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The Collected Writings of
Hermann August Seger

THE COLLECTED WRITINGS

OF

HERMANN AUGUST SEGER

Professor at the Royal Technical Institute, Berlin
Chief of the Chemical-Technical Experiment Station, Royal Porcelain Factory, Berlin

PREPARED

From the Records of the Royal Porcelain Factory at Berlin

BY

DR. H. HECHT and E. CRAMER

TRANSLATED BY THE

MEMBERS OF THE AMERICAN CERAMIC SOCIETY

EDITED BY

ALBERT V. BLEININGER, B.Sc.
Instructor in Ceramics, Ohio State University

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CONTENTS

B (*Continued*)

IV. Treatises Referring to Whiteware

PAGE.
1. Examination of Some Fine Whiteware Bodies - - 553
2. Defects of Glazes and Their Causes - - - 557
3. A Discussion of Glazes with Special Reference to Whiteware Glazes Free from Lead - - - - 593
4. Whiteware Glazes with Use of Barium Sulphate - 634
5. The Influence of Sulphuric Acid on Glazes and Bodies - 645
6. Underglaze Colors and Their Preparation - - 651
7. Grinding Mills for Glazes and Colors - - - 667

V. Treatises Referring to Porcelain

1. On the Relation between the Composition of the Sennewitz Kaolins and their Behavior in Burning - - 669
2. The Composition of Some Foreign Hard Porcelain Bodies - 678
3. Some Raw Materials of the Porcelain Industry at Limoges 695
4. The Wegeli Porcelain Bodies - - - 700
5. Colored Porcelains - - - - - 704
6. The Composition of a Bisque Body - - - 707
7. Japanese Porcelain, Its Decoration, and the Seger Porcelain. The Red and Flamed Cuprous Oxide Glazes - - 708

C

Reports of Travel and Letters (Polemics)

I. Letters from the Year 1872

1. The Oldenburg Clinkers - - - - 759
2. The Belgian and Lower Rhine Brick Industry - - 762
3. The Staffordshire Potteries - - - 769
4. The English Brick Industry - - - - 783
5. Notes on the Manufacture of Bricks Pressed from Clay Dust 801
6. The Manufacture of Black Vitrified Bricks - - 807
7. The Nassau Stoneware District - - - 809

II. Reports from Vienna Exposition, 1873

1. The English Pottery - - - - 821
2. The Indian Claywares - - - - 829
3. The French Clay Industry - - - - 830

PAGE.
4. Brick Machines - - - - - 835
5. Manufacture of Sewer Pipes - - - 843
6. The Wienerberg Brick Yards - - - - 848
7. Means of Transportation - - - - 860
8. Italian Pottery - - - - - 866
9. Stoves - - - - - - 869
10. The Belgian and Dutch Clay Industries - - - 874
11. The German Clay Industry - - - 877
Notes on the Brick Industry of Northern France - - 883

III. Report from the Paris Exposition, 1878

1. Brick Products and Brick Machines - - - 890
2. Wall and Floor Tiles - - - - - 897
3. Fine Claywares - - - - - 902
Examination of Two Floor Tiles - - - - 920
The Manufacture of Gas Retorts - - - 921

IV. Report from the Berlin Trades Exhibition, 1879

1. Face-Brick and Terra-Cotta - - - - 933
2. The Manufacture of Stoves - - - 935
3. Majolica - - - - - - 940
4. Clay-Working Machinery - - - - 944
5. Porcelain and Whiteware - - - - 946
The Clay Industry of the Island of Bornholm - - 950
The Exhibition of the Union Centrale des Arts Decoratifs, in Paris, 1884 - - - - - - 959
Phenomena and Precautions To Be Observed in the Burning of Calcareous Clays. Reply to an Article by Olschewsky - 971
Public Letter of Olschewsky to Dr. Seger - - - 987
Public Reply of Dr. Seger to the Letter of Olschewsky - 992
The Hainstedt Clays. A criticism Directed against the Work of Dr. Strohecker - - - - - 999
Reply of Dr. Strohecker - - - - - 1002
Some Melting-point Determinations of a Number of Professor Seger's Cones, by Dr. C. Bischof - - - 1005
Reply by Dr. Seger - - - - - 1008
Reply by Dr. C. Bischof - - - - 1013
Note on the Determination of Temperature in Kilns by Means of the Pyroscope Cones, Dr. Seger - - - 1017
On the Question of Standard Cones, by Dr. Seger - 1020
Note on the Polemics Regarding the Seger Pyrometric Cones, by the German Editors - - - - 1021

PAGE.
Pyrometric Trials of Seger Standard Cones in Different Kiln Systems, by Dr. P. Jochum - - - 1022
Pyrometric Measurements, by Dr. Seger - - - 1024
The Coloration of Claywares by Iron at High Temperatures. Criticism of an Article by Dr. Knapp - - - 1027
Coloration of Porcelain and Glass in the Glost Kiln, by Dr. Knapp 1038
Coloration of Porcelain in the Glost Burn by Dr. Seger - 1041
The Porcelain Hard Fire Red - - - - 1042
Correction to a Statement by Professor A. Schmidt - - 1044

D

Uncompleted Work and Communications from the Records of the Royal Porcelain Manufactory

Communications Concerning the Testing of Brick-clays by Members of the German Association of Clayware Manufacturers 1047
Results of an Inquiry Made by the German Society of Clayware, Lime and Cement Maufacturers, into the Fuel Consumption of different Kiln-systems - - - - 1067
Mechanical Examination of a Brick Clay - - 1108

Investigations of Materials for the Brick and Pottery Industries

1. Clay from Carlsburg (Convent Loccum) - - 1111
2. Clay from Puchau - - - - 1112
3. Brick Clay from Wickendorf, near Schwerin - - 1113
4. Brick Clay from Helmstedt - - - 1114
5. Clay from Förderstedt, near Schoenebeck - - 1115
6. Clays from Hainstedt - - - - 1116
7. Clays from the Eifel - - - - - 1118
8. Investigation of a Tin Glaze for Stove Tiles - - 1119
9. Glaze for the Velten Clay - - - - 1121
10. Examination and Preparation of a Smalt - - 1121
11. The Cause of the Destruction of the Zinc Trimmings of a Berlin Market House - - - - - 1121
12. Faulty Burns in the Pottery Industry - - 1124

Examination of Materials of the Fire-Brick and Stoneware Industries

1. Analyses of Fire-Brick, Glass, Pot and Stoneware Clays - 1127
2. Analyses of Fire-Brick, Etc. - - - 1130
3. Examination of the Clays from Grossalmerode - - 1131
4. Opinions on the Raw Materials Suitable for the Manufacture of Plumbago Crucibles - - - - 1136

PAGE.

Examination of Materials for the Whiteware and Porcelain Industries

1. Analysis of the Whiteware Clays of Lothain - - 1137
2. Tests of Kaolins - - - - - 1139
3. Concerning the Cause of the Rolling-up of the Glaze Layer - 1147
4. Concerning the Origin in Yellow Spots on Biscuit Ware 1148
5. The Investigation and Method of Preparation of a Black Color for Muffle-fire - - - - - 1149

Index - - - - - - 1153

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B. TREATISES WHICH RELATE TO SPECIAL BRANCHES OF THE CLAY INDUSTRY

IV. ESSAYS REFERRING TO WHITEWARE

Examination of Some Fine Whiteware Bodies

Professor Edward Orton, Jr., Translator

The bodies, whose composition is communicated in the following note, have been collected on travels undertaken by the order of the Minister of Commerce. They originate from factories whose size as well as the quality of their products causes them to occupy a high rank.

The bodies designated as A and B are worked in two French establishments, and the bodies C and D come from a Belgian factory, the first being used for fine table ware, the second for more ordinary articles. Body E is of German origin. The factories located at widely distant places, of course, work very different raw materials, and have also widely different methods of preparing the body.

Body A is obtained by simply washing and sieving the raw materials just as nature has furnished it. It consists of the washed kaolin of St. Yrieux, high in feldspathic residue, a fat and a fine sandy clay; an addition of feldspar as such, or ground silica as quartz, flint or sand, does not take place.

Body B is made up of kaolin and a plastic clay of unknown French origin which receive an addition of ground Norwegian feldspar and pure quartz sand.

For the bodies C and D, English kaolin (china clay), plastic clay from Belgium, ground English cornish stone and flint from Dieppe are used. The difference between the bodies consists in the fact that the former is higher in kaolin and cornish stone, the second higher in plastic clay. The origin of the raw materials for body E is not known to me.

The biscuit made from the bodies is in every case pure white in color, and with the exception of body A, which appears least resistant, cannot be scratched with a steel blade. Of the others body B seems to be the hardest one, possessing the clearest ring.

The examination was carried out in such a way that the amounts of the separate constituents of the unburnt bodies were determined as well as the proportion of the definite mineral compounds represented by them, that is, the quartz, the feldspar and the hydrous silicate of alumina. This separation was made, according to the method described in detail in a previous essay, by heating with sulphuric acid which decomposes only the aluminum silicate (the real plastic clay substance of the kaolin and plastic clay), while the quartz and feldspar remain unattacked. The results of the analyses are shown in the table on page 556.

On comparing the column of this table which expresses the chemical composition of that part of the body decomposed by sulphuric acid and representing in its main part, at least in case of the purer clays in question, hydrous silicate of aluminium which gives to the body its plastic properties we find a remarkable agreement of the figures. This result corroborates previous investigations concerning the constitution of kaolins and plastic clays, and shows that in general we are dealing, in the plastic constituent, with a factor chemically as constant as the quartz and feldspar of the bodies. While, however, quartz and feldspar in the finely-powdered condition in which they are brought in, either intentionally or by the washed clay materials, do not show any physical divergences, this cannot be said of the hydrated aluminium silicate, the real clay substance. According to previous investigations the less plastic clay substance of the kaolins shows some chemical differences from the clay substance of the plastic clays, of the lignite formation, inasmuch as in the latter the content of water is somewhat smaller and the alkali content correspondingly higher, but these differences are not so great that definite conclusions can be drawn from the chemical analysis as to whether the clay substance is derived from a kaolin or a plastic clay. The rational analysis gives definite starting-points in regard to the content of quartz and feldspar, and also as to the amount of clay substance, but tells nothing as to its degree of plasticity. In respect to the last point, empirical tests must always be made based on the rational analysis in order to determine the ratio between kaolin and plastic clay and to produce the desired condition of plasticity. But these empirical tests are much simplified and their success assured since it is easy to maintain the other factors, the content of quartz and feldspar constant, by a simple calculation. Since clays contain varying amounts of these constituents by simply replacing plastic clay by kaolin and *vice versa*, the other relations are changed at the same time, and the degree of this change is not known.

An example might illustrate this: Supposing it is desired to produce a body of the physical constitution of the French body B from German raw materials and there are selected washed kaolin from Sennewitz as it is used in the Royal Porcelain Factory, containing 65 per cent of clay substance and 35 per cent of quartz powder, plastic clay from Ebernhahn found to contain 86 per cent of clay substance and 14 per cent of quartz powder and ground feldspar and quartz and starting with a ratio of kaolin to plastic clay of 1 : 2. Thus one-third of the clay substance or 17.87 per cent is brought in by the kaolin and two-thirds or 35.74 per cent by the plastic clay. We now have the following simple calculation:

65 : 17.87 = 100 : x = 27.49 parts of Sennewitz kaolin,
86 : 35.74 = 100 : y = 41.56 parts of Ebernhahn clay,
in addition 21.22 parts of ground quartz,
9.73 parts of feldspar,

100.00 parts of body.

27.49 pts. Sennewitz kaolin	=	17.87 clay sub. +	9.62 quartz,	
41.56 pts. Ebernhahn clay	=	35.74 clay sub. +	5.82 quartz,	
21.22 pts. ground quartz	=		21.22 quartz,	
9.73 pts. feldspar	=			9.73 felds.
100.00 parts of body	=	53.61 clay sub.,	36.66 quartz	9.73 felds.

This corresponds to body B.

	A.			B.			C.			D.			E.		
	Total.	Not decomposed by sulphuric acid. (Quartz and feldspar.)	Decomposed by sulphuric acid. (Calculated to 100.)	Total.	Not decomposed by sulphuric acid. (Quartz and feldspar.)	Decomposed by sulphuric acid. (Calculated to 100.)	Total.	Not decomposed by sulphuric acid. (Quartz and feldspar.)	Decomposed by sulphuric acid. (Calculated to 100.)	Total.	Not decomposed by sulphuric acid. (Quartz and feldspar.)	Decomposed by sulphuric acid. (Calculated to 100.)	Total.	Not decomposed by sulphuric acid. (Quartz and feldspar.)	Decomposed by sulphuric acid. (Calculated to 100.)
Silica - -	61.71	29.87	47.00	67.45	43.24	45.56	65.92	37.87	47.89	61.70	29.97	46.13	64.25	40.79	45.39
Alumina - -	26.69	1.39	37.35	21.59	1.89	37.07	23.62	2.14	36.00	27.01	0.74	38.17	21.46	1.78	38.30
Ferric oxide	1.14	—	1.68	0.59	—	1.11	0.59	—	1.01	0.61	—	0.89	0.54	—	1.04
Calcium oxide -	trace	—	trace	—	—	—	trace	—	trace	0.65	—	0.94	2.38	2.38	—
Magnesium oxide	0.06	—	0.09	0.51	—	0.99	0.22	—	0.38	0.25	—	0.36	trace	—	—
Potash -	1.30	1.01	0.42	1.92	1.26	1.24	1.48	1.43	1.11	1.32	0.50	2.16	1.97	1.09	3.69
Soda - -	—	—	—	0.24	—	0.45	0.60	—		0.67	—		1.03	—	
Carbon dioxide	—	—	—	—	—	—	—	—	—	—	—	0.00	1.99	1.99	—
Water and organic matter -	9.24	—	13.64	7.23	—	13.61	7.24	—	12.37	8.11	—	11.77	6.12	—	11.83
	100.14	32.27	100.18	99.53	46.39	100.03	99.37	41.44	96.76	100.32	31.21	100.42	99.74	43.66	99.98
Clay substance		67.73			53.61			58.56			68.79			51.97	
Quartz (powder)		24.63			36.66			30.36			27.38			34.50	
Feldspar -		7.64			9.73			11.08			3.83			9.16	
Calcium carbonate - -		—			—			—			—			4.37	

If, however, such a body on being tried has proved sufficiently plastic but was too dense and not white enough, and an increase in kaolin is deemed advisable, on bringing in half of the clay substance = 26.80 per cent of B by kaolin the calculation would be:

65 : 26.80 = 100 : x = 41.23 parts Sennewitz kaolin,
86 : 26.81 = 100 : y = 31.18 parts Ebernhahn clay,
also 17.86 parts ground quartz,
9.73 parts feldspar,

100.00 parts body.

41.23 Sennewitz kaolin = 26.8 pts. clay sub. + 14.43 quartz,
31.18 Ebernhahn clay = 26.81 pts. clay sub. + 4.37 quartz,
17.86 quartz = 17.86 quartz,
9.73 feldspar = 9.73 felds.

100.00 parts body as before, = 53.61 clay substance 36.66 quartz 9.73 felds.

For practical purposes the rounded numbers are, of course, to be used.

The Defects of Glazes and Their Causes

PROFESSOR EDWARD ORTON, JR., TRANSLATOR

In the following discussion, in attempting to explain the causes of some of the defects of glazes, which often bring very severe losses to those who work with them practically, it is likely that some gaps will appear, and I hope that they will be excused on the ground that, until the present time, very little scientific investigation has been devoted to the subject, and also that many of the phenomena, when traced back to these causes, appear in different places in very different ways, according to the local conditions and methods of treatment, according to the composition of the body and glaze, the construction of the kiln, the kind of fuel, etc., and also because the terms used in this business have often only a local significance.

I. Chemical Composition of Glasses and Glazes

By the term "glaze," we understand in general every superficial coating on clay ware covering either the whole surface or a part of it, which is intended either to prevent the absorption of liquids or gases, or to serve as a decoration, or as a ground layer on which to apply the painting in colors, enamels or metals. These superficial coatings are always and inseparably connected with the idea of a ceramic product, of being fixed by a fire process on to the clay body which is the carrier of the glaze, and where this specification fails to apply, then the thing is not a glaze, and glittering coatings similar to glazes which are applied on the wares in other ways than this, will not be included in this discussion.

The composition and the properties of the glazes vary in a still higher degree than the clays and bodies made from them which are used in the ceramic industries. The appearance itself allows this to be noticed: in the one case, the glaze forms a clear transparent glass, and in the next it is partly clouded or wholly opaque; it may be colorless or colored in the most various manner by the dissolved metallic oxides. Again, the glaze appears as a clear glassy mirror, with splintering sharp fracture, and in another case it will show a more or less dull surface, and a stony fracture. A glaze can therefore always be defined as "a more or less glassy coating" whose ingredients are either melted to a vitrified slag or porcelain-like mass (as in the dull glazes) or to a glass or enamel (as in the clear and opaque glazes).

The name indicates, and it is apparent even to the eye of one who is not familiar with the chemical nature of glazes, that the glazes and glasses unite many important qualities and are in fact related substances.

This is the case, and in the discussion of the phenomena which mark the glazes, we will frequently refer back to the phenomena which characterize the manufacture of glass which are better understood from the scientific standpoint, and which are easier to approach than is the case with the glazes for clay wares. A study of the analyses of glasses used in ordinary industrial operations is extraordinarily useful in the study of the phenomena occurring in the melting of glazes.

Considered from the chemical standpoint, glazes and glasses are closely allied compounds. In both cases the combinations are between silicic acid on the one, and basic, flux-forming metallic oxides on the other side. Boracic acid often serves in one as in the other to replace a part of the silicic acid and the basic fluxes are, in both, potash, soda, lime, magnesia, oxide of lead, and alumina, and also when colors are desired, the oxides of cobalt, nickel, manganese, ferrous and ferric oxides, cuprous and cupric oxides, chromic oxide, and small quantities of gold, uranium, or iridium sesquioxide are used as fluxing material.

Opacity is obtained in both cases by tin oxide, antimonic acid, arsenic acid, calcium phosphate, or large quantities of alumina. There are, as a rule, three or four flux-forming oxides present, except in a few of the lead glazes in which only lead oxide and silica are used, and of these three or four, one is always represented by an alkali, either potash or soda. It is seen from this, that as far as the materials used in forming the two substances are concerned, there is no qualitative distinction, but there are notable distinctions in two other respects: (1) in the proportion in which the ingredients are used, and (2) in the manner in which they are united into a glassy mass.

The quantitative composition of the ordinary glasses varies inside rather narrow limits. So far as it is necessary to express the same, the limits of the safe manufacture of glass must correspond on the average to the empirically expressed formula by Benrath: $0.5\ Na_2O$, $0.5\ CaO$, $2.5\ SiO_2$.

The minimum content of silica, two equivalents to one of base-forming oxides, and the maximum, three equivalents of silica to one of the base-forming oxides, are the actual limits. Glasses which attain these limits would be considered very difficult to work.

In the normal formula of glass, the soda may be replaced by potash, and the lime by baryta, magnesia, lead, or coloring oxides in equivalent proportions; the ratio of the alkalies to the lime, or to its substitutes, does not exceed as a rule the limits of the proportion; *viz.:* soda : lime :: 0.5 : 0.5 to 0.33 : 0.66. An important alumina content occurs only in very ordinary bottle glasses; in other glasses in common use, the small alumina content comes from the impurities of the materials used in the manufacture, or from the body of the crucible or pot in which the glass was melted, and the alumina is therefore an unimportant ingredient in glasses.

The narrow limits which are allowed in the chemical composition of the glasses on account of practical reasons, compel at the same time a correspondingly small variation in the fusibility. Comparing the variations which occur in the melting-point of glazes, with those of glasses, one will see that only those glasses which are made for some special purpose, such as the lead-and-boracic-acid optical glass, and the hard potash-lime glass used for chemical purposes, exhibit much variation in the heat-resisting power.

In those glassy compounds which pass under the name of glazes, the requirements which are made as to their qualities are very different from those which characterize the technology of glass manufacture, especially as to fusibility, and therefore as to composition. The glaze occupies, as far as its mere bulk is concerned, a very secondary position compared with the bulk of the clay body which bears it on its surface, and on this account, its properties are principally controlled by the properties of the clay body. Hence the fusibility of the glaze, varies in very wide limits, according to the fusibility, or rather to the ease of vitrification which the clays and the bodies used for their formation exhibit; therefore, the quantitative proportions of the chemical elements given above as the ingredients of glazes, vary inside of wide limits.

If we wish to express the outside limits of composition found in the glazes in actual use, by means of chemical formulas, we would have as the most easily fusible type, such as are used for ordinary earthenware and for fine French faience, as follows:

$$RO : 1.5\ SiO_2 \text{ to } RO : 3\ SiO_2,$$

which are analogous to the very fusible optical and lead flint glasses.

For the harder glazes of the German and English whitewares, the limits of the composition would be expressed by the formulas

$$RO, 0.1\ R_2O_3, 2.5\ SiO_2 \text{ to } RO, 0.4\ Al_2O_3, 4.5\ SiO_2$$

and for the porcelain glazes, by the formulas

$$RO, 0.5\ Al_2O_3, 5\ SiO_2 \text{ to } RO, 1.25\ Al_2O_3, 12.5\ SiO_2.$$

In practice we find that every intermediate step between the limits given, is likely to be produced, according to the variation in bodies, and the varying requirements with which bodies and glaze are expected to comply. In explanation of the formulas given above, it must be remarked that RO stands for the sum of all the flux-forming oxides each according to its chemically equivalent value, that is potash, soda, lime, magnesia, baryta, lead, and the coloring oxides, and in the expression SiO_2, boracic acid is often included with the silicic acid, in proportions varying from 0.25 to 0.05 of the silica contents.

The alumina, which is always present in glazes, with the exception of a few of the most easily fusible ones (a distinction from glasses, which do not carry alumina, except as a chance impurity) occupies a peculiar position in the formula, since it is excluded from the fluxes proper, and is also excluded from the materials which can replace the acid portion of the formula; it generally stands midway between the two, and there plays a characteristic and a very important part in the development of the qualities of the glaze, as we will see later.

To be sure that the formulas used above are understood, it should be explained that the content of alumina and silica including the boracic acid, are always reckoned by taking the content of fluxes as unity, and these fluxes are figured by adding the amounts expressing their equivalent weights. To the chemist accustomed to stoichiometric calculations, this method of expressing by general formulas the composition of substances is well understood; but to those not having any chemical knowledge, it would lead too far to attempt to explain here how to proceed to calculate the composition from the formula of a glaze, and indeed it does not seem necessary, for the production of a glaze according to the directions of chemical formula, can never be accomplished without the active assistance of a chemist. The objection may be raised against the above formulas, that they do not agree with the popular view of the constitution of glasses and glazes, and that they may be taken to mean that the silicic acid, contrary to the general view, is able to satisfy its affinities with any irregular quantities of basic metallic oxides, and forms with them fixed and stable compounds.

It must, therefore, be stated in order to avoid errors of conception, that in this manner of expression, none of the different views of the constitutional grouping of elements are antagonized in the least, and that the formulas merely express that the elements indicated are present in certain proportions, and it does this in a simple and graphic manner, from facts which can only be deduced from an analysis of the material.

With reference to the part which the separate metallic oxides take in the formation of the glaze, it must be remarked that in most cases, no single one is used for the production of a glass or glaze, but that several are generally employed; glasses and glazes should always be mixtures of silicates, and only when this is the case, do the compounds take on the character of a full-fledged glass.

In the most easily fusible glazes, whose fusing-point occurs at the temperature at which silver melts, the oxide of lead predominates in practical work as a flux. In the more difficultly fusible glazes used for the whiteware trade, whose fusing-point ranges from the melting-point of silver up to a little above that of gold, the lead oxide becomes less important, as the glaze becomes less fusible, and the alkalies and the alkaline earths, potash, soda, lime and magnesia, baryta, alumina, and iron become constantly more important as fluxes.

In the very difficultly fusible glazes used for porcelain, whose fusing-point often exceeds the melting-point of wrought iron, attaining a white and even a bluish heat, lead oxide is totally absent, and the glaze contains only the alkalies and earths as fluxes, except in the case of a few soft Chinese porcelains.

The glazes can be distinguished from the other fused compounds of similar qualitative composition, termed glasses, not only by the wider limits which mark their composition quantitatively, but also in the manner and methods in which the separate compounds are united to form a chemical compound or a mixture of such. The materials which are in actual use as ingredients for both glass and glaze are given in the following paragraph.

The raw materials which furnish the constituents of glass as well as of glazes, are as a rule selected from the following compounds:

For the introduction of silica:

Silica in pure form (as quartz sand, sandstone, crystalline quartz, infusorial earth, flint) and silicious minerals (feldspar, sandy clays, etc.)

For the introduction of boracic acid:

Borax (sodium borate), boracite (magnesium borate), sodium boroncalcite (sodium and calcium borate), and boracic acid.

For the introduction of potash:

Potash (impure potassium carbonate), nitre (potassium nitrate), feldspar (potassium and aluminum silicate).

For the introduction of soda:

Borax, soda (impure sodium carbonate), sulphate, common salt, and cryolite (sodium and aluminum fluoride).

For the introduction of lime:

Marble, limestone, and chalk (all carbonates, in various degrees of purity), gypsum (calcium sulphate).

For the introduction of magnesia:

Talc (magnesium silicate), magnesite (magnesium carbonate), dolomite (magnesium and calcium carbonate).

For the introduction of barium:

Barite (barium sulphate), witherite (barium carbonate).

For the introduction of lead oxide:

Litharge (PbO), galena (lead sulphide), red lead (lead peroxide and oxide), tin ash (tin and lead oxides).

For the introduction of alumina:

Feldspar, clays, and other aluminous minerals, and finally cryolite.

According to the contemplated composition of the glass or glaze, the cost of the ingredients, the purity of the materials accessible to him, the maker will choose from the materials at his disposal, and make from them a receipt for use.

For the preparation of a glass, the raw materials only need drying and calcination, as well as grinding and mixing. The glass batch is then melted in pots or tanks, heated up to complete fluidity, so that air-bubbles and impurities which are taken up by the glass will be separated as the so-called "glass gall." By this complete fusion and the removal of the glass gall, the glass can be purified, and is then ready for the working process after it has been brought to a tough viscous condition by cooling somewhat.

In the production of glazes from practically the same raw materials, the method of preparation must be noticeably different. In the manufacture of glass, the ingredients are fused together from a dry condition, while the ingredients of a glaze are brought upon the porous clay body, in a more or less thin coating, so that it must be distributed on the surface to be glazed, in a finely ground slip, by dipping or pouring, and it must adhere there, by the absorption of the water by the shard.

This sort of application makes it necessary that, if one wants to attain a regular composition, or to have uniformity of behavior, in the glaze layer, that he should place all the ingredients in a condition insoluble in water, for otherwise the greatest part of the glaze would be absorbed by the body. Among the materials named above, are a large number which are soluble in water, especially borax, sodium boroncalcite, potash, saltpeter, soda, salt-cake, common salt, and gypsum. So far as these come in use it is necessary to bring them into a condition insoluble in water. This is done by melting them together to form an easily fusible glass with part of the ingredients, insoluble silicious materials such as sand, feldspar, or also lime and lead compounds, which are resistant to the solvent action of water. This glass, which is called frit, because it is not brought up to a temperature at which it becomes thinly fluid, is then ground fine and mixed with the other ingredients of the glaze in the mill.

In some cases, for example, in the preparation of the enamels for ordinary faience, all the ingredients of the glaze are fritted together and after washing out all the portions not taken up by the glaze (usually common salt), the whole is used direct as a glaze. After the application, with or without the use of a frit, of the finely ground glaze constituents on the surface of the ware, the burning follows, *i. e.*, the melting and glassifying of the ingredients of the glaze.

Conditions do not permit that the heat should be raised to the point where the glaze becomes thinly fluid, for part would run off from thick spots and inclined places, and part would be absorbed by the porous clay-body, and the smoothness thereby be lost. The heating must only be allowed to approach the tough fluid consistency of the glassy covering. This circumstance requires, if one wishes to attain the production of a good homogeneous glass, that the glaze constituents shall be very finely ground, and that they shall be prevented from settling out owing to their different specific gravities from the glaze slip.

The last is guarded against by keeping the glaze constantly in motion by the use of paddles or of some sort of pump. Also, on account of the viscous condition of the glaze necessary, the separation of the air bubbles is greatly impeded, as well as the separation of such impurities of the raw materials which are not taken up by the glass as it forms, and which can be separated in ordinary glass as glass gall (salts of non-volatile acids). It is seen from this, that in the manufacture of a glaze, it is not only necessary to practice a more careful preparation of the ingredients, but also to exercise a more careful selection of the same, as to purity, than is the case with glass, if it is expected to avoid troubles due to the conditions mentioned above.

II. INFLUENCE OF THE GLAZE INGREDIENTS ON THE FUSIBILITY

After the meaning of the term glaze and the distinction between the glazes and the glasses has been brought out in the foregoing section, we will proceed to investigate how the glazes must be altered, in their quantitative composition, in order to attain the degree of fusibility necessary for a smooth fusion, which depends on the various purposes; that is, the kind of body, the method of the subsequent treatment by underglaze colors, fusible colors, enamels, lusters, metals, etc., and also upon the available means of control.

The manufacture of a glaze of any desired degree of fusibility, is of great importance in glaze work. Since the body quantitatively, is much the largest part of the ware, and since it is the vehicle of the forms and properties which it is desired to attain, it is always the foundation of the manufacture, and it is seldom advantageous or permissible to vacillate as to this foundation; therefore, it is generally best to fit the glaze by changing its composition to a fixed constant body, while it is seldom the case that it is advantageous to change a body to fit any special glaze.

One of the most important adjustments, between body and glaze, is that of regulating the melting-point of the latter. By the term melting-point should always be understood that temperature which is necessary to unite the ingredients of the glaze (after they have been made insoluble by fritting, mixed finely, and have been applied on the surface of the ware, in the form of a very thin coating), so that they form a glassy coating with a shiny surface, without reaching that degree of fluidity which would cause it to be absorbed by the porous ware, or to flow off from its surface.

The fusibility finds its expression in the quantitative composition of the glaze. The following points are of importance in considering this fusibility:

A. The ratio (expressed in equivalents) between the fluxing bases and the silica;

B. The kind of fluxes which are present;

C. The relation of the alumina to the fluxes and to the silica;

D. The ratio between silica and boracic acid, in case the latter is used as a partial substitute for it.

A. The fusibility of glasses is, in the presence of equal proportions of the fluxes, dependent on the silica content. The silica is by itself infusible, and it becomes fusible only when it unites with some metallic oxide. The melting-point is the higher, the richer the compounds are in silica, and at the same time the latter become more viscous and stringy, a property which they lose more and more, as the fluxes increase.

In the preceding section, we have made a statement of the fact that the composition of the ordinary glasses can be illustrated by the formula Na_2O, CaO, $5\ SiO_2$, or if one designates the sum of the bases as RO, by the formula RO, $2.5\ SiO_2$, which is a body corresponding to the degree of saturation of a two-and-one-half-fold silicate. If the constitution becomes more or less acid, it takes on properties unfavorable for working. In the first case, by increase of the silica, it acquires the property of easily devitrifying, and in the second, by a decrease of silica, it loses its ductility and viscous nature, the property necessary for blowing.

Devitrification consists of a separation of silicic acid, or of silicates in crystalline form, which cloud the glass, and destroy the gloss of the surface, and which change it to a porcelain-like mass, if it is heated for a long time up to the temperature of softening. A resolution of such separations only takes place, when the glass is heated again up to the very liquid condition.

Although by increasing or decreasing the silica content of glazes in proportion to the fluxes, variations in the fusibility of the glazes can be produced, still, in the easily fusible glazes free from or low in alumina, which most resemble the glasses in composition, one cannot vary far from the limits assigned to the glasses, without incurring the faults corresponding to those of the glasses.

Both faults, which are very noticeable in the products of the clay industries, and which, in too high a silica content, are seen in a clouding of the glaze by a long glost-fire, or by a slow cooling, and in too low a silica content, are observed in the running off of the glaze, or the soaking into the porous body, belong to the commonest which are met in practical work. The means of correcting these faults are to be inferred from the facts already mentioned.

B. The fluxes mentioned in the preceding section do not all work with equal vigor in fusing silica. The law established by Richters and Bischof, concerning the fusibility of clays, "that equivalent proportions of fluxes exert an equal influence on the fusibility," and which appears to be approximately correct for the very high temperatures employed in clay testing, and for the very small quantities of the fluxes coming into action in the clays, has no bearing on the glasses and glazes, far richer in fluxes and melting at far lower temperatures.

For those metallic oxides which yield colorless glasses or glazes, the following order of fusibility may be stated: lead, barium, potash, soda, zinc, lime, magnesia, alumina. By this "order of fusibility" it is meant to be understood, that if in any designated lead glass, the lead were replaced by an equivalent quantity of one of the other oxides, the resulting glass which is chemically an analogue of the first, would be in reference to its fusibility in the proper place given in the series.

The coloring oxides, whose introduction into a glass or glaze may noticeably affect the fusibility of the same, behave in the same way and on this account, the popular view that the colored glasses are simple solutions of the oxides, can scarcely be held as tenable. Among these, copper oxide works most powerfully as a flux and nearly approaches lead oxide in activity; then follow in the order named: manganese, cobalt, iron, uranium, chromium, and nickel.

If one considers the first list he will find, and this is evidently not accidental, that the metallic oxides of high equivalent weights are at the top of the list in fluxing power and that the list ends with those of low equivalent weights. In the coloring oxides this is not the case, because their equivalent weights are so close to one another. In a list or series of stoichiometrically equivalent glazes, the percentage content of silica will be smaller in direct proportion as the weight of the equivalent of the flux increases. Those glazes which contain the most active fluxes are therefore always the lowest in silica percentages, and therefore the softer and most easily attacked. It is seen from this why lead oxide is always preferred as a flux for the easily fusible glazes, and why in these, alumina steps very much into the background, and also why in the hard fire glazes the alumina often is made an important constituent, while lime and magnesia predominate over the alkalies.

It is not only the kind of flux used, which governs the fusibility of a glaze; the number of the fluxes is also of importance. It has already been stated that, with the exception of lead oxide, which like the alkalies is able to form a transparent colorless glass by itself, at least two fluxes must always be present to make a glass. The alkali metals can, on this account, hardly be said to form glasses at all, because their compounds are all soluble, even the tetrasilicate. The oxides of the alkaline earth metals alone form no transparent glasses, but only stony or slag-like silicates. Therefore, in order to produce a transparent glass, it is necessary to have at least two fluxes present, one of which is, as a rule, an alkali. And it is well known in practice, if not yet wholly explained by science, that the fluidity increases with the number of the fluxes present. For example, a lime-soda-potash feldspar is more fusible than a soda-potash feldspar or a lime-potash feldspar by itself, which possesses the same degree of acidity.

C. Alumina, although it plays the part in its entire behavior to silica of a basic body, and goes as such into the glasses and glazes which always contain an excess of acid, cannot be regarded as a real flux, at the temperatures which here are under discussion for, by increasing additions, it increases the melting-point like silica, but in a very striking manner. It may be regarded as operating as a flux in the highest degree at the high temperatures which are used in the porcelain fire, and at the same time in the presence of relatively small quantities of the other fluxes, taking the same kind of a position it takes in the refractory clays, according to the researches of Bischof.

The introduction of alumina into a glaze, affords an opportunity or means to raise the melting-point of a glaze, and at the same time to change the ratio of the real fluxes to the silica, in such a manner, that the degree of saturation of these to each other will not exceed the limiting values already given (that between a bisilicate and a trisilicate), without risking the faults, which are to be expected in the glazes free from alumina; *i. e.*, tendency to devitrification, and the running off or soaking in of the glaze. This property or method of operation of the alumina renders it probable, that it is not, as some observers have shown (Ebell, Benrath), merely dissolved as such in the fluid glass, but that it is part of a silicate in double combination with the silicates of the other fluxes.

If we recast the calculations of the limiting values given in the first part of this treatise, of the composition of the more difficultly fusible whiteware and porcelain glazes, in such a manner that the alumina is not separated from the other fluxes, but is calculated with them according to its threefold greater capacity for saturation with silica than that possessed by the other monoxides, we will obtain a formula which in fact corresponds to that of the alumina-free or low alumina glasses and glazes; that is, its saturation point will lie between the bi- and trisilicate, and will come closer to the first, rather than to the last, on account of the property which alumina has of giving a viscous nature to glasses or glazes.

If one calculates the alumina as being equal to 3RO, because both contain equal contents of oxygen, and correspond to equal oxygen contents in saturation with silica, the formulas given above will shape themselves as follows:

Whiteware glazes, minimum
$RO, 0.1\,Al_2O_3, 2.5\,SiO_2 = 1.3\,RO, 2.5\,SiO_2 = RO, 1.92\,SiO_2$.
Whiteware glazes, maximum:
$RO, 0.4\,Al_2O_3, 4.5\,SiO_2 = 2.2\,RO, 4.5\,SiO_2 = RO, 2.05\,SiO_2$.
Porcelain glazes, minimum:
$RO, 0.5\,Al_2O_3, 5\,SiO_2 = 2.5\,RO, 5\,SiO_2 = RO, 2\,SiO_2$.
Porcelain glazes, maximum:
$RO, 1.25\,Al_2O_3, 12\,SiO_2 = 4.5\,RO, 12\,SiO_2 = RO, 2.55\,SiO_2$.

It is seen from this, that considered from this point of view, the difficultly fusible glazes in actual use correspond in reference to their degree of saturation, to the practical conditions actually required in the glass industry, that they correspond to a silicate midway between a bi- and a trisilicate, and that they must not approach very closely the trisilicate ratio, if they are expected to escape an inclination to dullness by so-called devitrification on slow cooling, which in the clay industries cannot well be avoided.

D. Boracic acid shares with silica the property of forming with the metallic oxides, which are here receiving discussion, glassy amorphous compounds which, with the exception of the alkali oxides, are insoluble in water. Boracic acid and silica glasses are miscible in all proportions. They can be distinguished from each other, by the fact that the borax glasses are noticeably more fusible in otherwise analogous compounds, than the corresponding silica glasses, which is due to the fact that the boric acid is itself brought into fusion by a low heat. A replacement of a part of the silica by boric acid which is similar to it in its behavior, serves as an excellent means of lowering the melting-point of a glaze without altering its composition in other respects, especially its degree of saturation. The preceding statements give us the means of altering a glaze in whichever way it may need as to its fusibility, without at the same time incurring new faults through these changes, especially tendency to devitrification or too great softness (running off or soaking into the body).

If a glaze is too fusible for the purpose for which it is to be used, owing to the composition of the body, it can be made more difficultly fusible by the following means:

1. By raising the silica content and thereby lowering the content of the basic fluxes. A limit must be observed in this respect, in the fact that the acidity of the glaze must never exceed a trisilicate, and never fall below a bisilicate. In the first case, an inclination to devitrification ensues, and in the last case, a tendency to running off from the ware, which is the more marked the lower the glaze is in alumina.

2. By the substitution of a less energetic flux for a more intense one, maintaining always the same acidity; for instance, substituting a part of the lead oxide by potash, soda, lime or magnesia, according to equivalent proportions.

3. By decreasing the number of the fluxes present, maintaining always the same acidity ; for example, the use of potash or soda alone instead of potash and soda, or of lime or magnesia, instead of lime and magnesia. Of course, the substitution must be made according to equivalent proportions.

4. By the introduction of alumina, or the increase of the alumina content with a simultaneous increase of the silica content, provided that the acidity of the glaze be maintained inside of the limits given. In this case, one can best afford to approach the lower limit or reach it, for an increased content of alumina is much less likely to make the glaze too thin, and also is safe as to devitrification.

5. By a decrease of the content of boric acid, where this has been used, and by the substitution of an equivalent quantity of silica.

Should the opposite change be desired, that of making the glaze more fusible, the rules given here are to be reversed.

III. Chemical and Physical Relations between the Composition of Body and Glaze

It is well known to every manufacturer that glazes, if made with all care and from suitable materials, answer all the requirements which may be made on them as glassy masses, but yet are often very far from giving satisfaction in regard to their combination with the clay base on which they rest. Great difficulties arise in the manufacture and use of glazes, from the union of two chemically and physically different substances, which do not occur in the glass industry to an equal extent, for in this case, it happens that if several glasses are to be united, the union is between very similar materials.

The principal difficulties which arise in the production of a faultless union of body and glaze lie in the different expansion which these experience when subjected to heat. It is a well-known property of all bodies, be they solid, liquid, or gaseous, that they increase in volume when they are heated, and return again to this volume when they cool down.

The amount of this expansion is variable with the different bodies, being considerable with the liquids and gases, and less with the solids, but with all it is a measurable quantity, if suitable instruments are at hand. The number which expresses this expansion in length or in volume on heating 1° C., is called the coefficient of expansion, and it applies to the contraction on cooling as well as to the expansion on heating. If two thin or plate-like bodies were bound together firmly, and if they have different coefficients of expansion, there must arise at the points of contact, a tension, which, if the bodies can be bent or are elastic, will produce a bending, and if they are hard and resisting, will produce a fracture of the weaker of the two. In fitting a glaze to a burnt clay body, we generally have to deal with two bodies of unequal expansion. So long as the temperature of a piece of clay ware covered with glaze remains high, so that the glaze is fluid or in a viscous condition, it can adjust itself to the expansion of the clay without trouble. But a tension arises the moment the glaze is fully hardened, owing to the different power of adjustment.

Since the clay as well as the glaze possesses only a very limited elasticity, or power of bending, the tension arising between the two layers, on cooling, will easily produce a cracking of one or the other in consequence. The tension arising through unequal expansion or contraction between the glaze and body is the ordinary reason for the very common faults of glazes, *viz.*, crazing and shivering.

If the contraction of the glaze is greater on cooling than that of the body (that is, the coefficient of expansion of the glaze is the greater of the two), the tension arising between the two through this inequality will produce a cracking of the glaze. The greater this difference is and the less elastic the glaze, the closer will the network of cracks become. The tension existing between body and glaze tends, if this difference is considerable, to produce crazing even while the ware is cooling, or soon after; in this case, the network will be very fine-meshed. If the tension is only weak, the small elasticity of the glaze may operate in the beginning against fracture, and hold out the longer, the thicker the intermediary layer which has formed by the absorption of the ingredients of the body by the chemical action of the glaze on the contact surface, but in the long run, this cannot prevent the crazing from taking place. Often the crazing takes place from an injury to the glaze by scratching it in use, especially on thicker parts of the layer, but generally it will occur during longer storage, often after months or even years, without any apparent reason for any disturbance of the balance of the contending forces. Cracks which arise relatively late generally form straight long lines which, in turned wares, follow spirally the marks of the turning on the body.

The phenomena are very different when the body and not the glaze has the greater coefficient of expansion, and therefore, the greater contraction. Then a tension arises, which is directed not towards cracking the glaze, but towards crushing it in the direction of the surface between the two bodies. On very much curved parts, the glaze will split off under the action of relatively small tension, by which the body suffers also, if the body is proportionately thin and the glaze is proportionately thick. With the flying pieces of glaze, small shell-like pieces of the body are torn away; thus edges of vessels crush in, the junctions of spouts, handles and feet, fall off, and under a heavy tension, the complete destruction of the body, its breaking into little pieces, with an explosive violence, and a scattering around of the fragments may take place.

Through this difference in the contraction while cooling but always only after the complete hardening of the glaze, a set of phenomena are produced whose more intimate study is very important for the technology of the clay industries, and it seems appropriate to give the results of a series of exact scientific researches, carried out on this line, without at this time giving the details of such an investigation.

To establish the coefficients of expansion of different bodies and glazes on little test plates made from them, would not be a difficult matter for one provided with the proper measuring apparatus, but such an estimation, even if its numerical value were high enough, so that the relation between body and glaze and the coefficients of expansion could be read off from it, would have but a limited value for practical working purposes. The absolute amount of the expansion or contraction under the influences of heating and cooling seems to be of less importance than the knowledge of the circumstances under which a change in the expansion is accomplished, and in what manner it operates.

As to whether a certain glaze and a certain body show a concordant expansion and contraction, we have the best means of determining by a trial of the substances themselves, if we fasten them together. As a rule, the materials which we might take up at random do not show such a concordance, and far oftener they show one or both of the defects of glazes previously characterized.

We come to the point where we can approximate the coefficients of expansion of the body and glaze to each other sufficiently for practical purposes, when we know in what manner the materials occurring in the glaze or body operate towards reducing or increasing the expansion or contraction.

Let us take, for example, in order to avoid all possible complications, a body and glaze made of the purest and best defined materials: a whiteware body made from pure, white-burning clay, flint and feldspar, and for a glaze, the simplest one possible, consisting of a flint glass mixture made from lead-oxide, soda, silica, and boric acid.

Let us next vary in the body one of its components, maintaining the others constant. A body constituted as above described, if its accidental ingredients are ignored, consists of clay substance, used as the binding agent, and quartz and feldspar used as leaning materials. If we raise in this body the percentage of clay substance, by addition of clay which is composed of pure aluminum silicate like the Zettlitz kaolin, for instance, (which can be had in the market with a purity of 97 to 98 per cent) by 5 per cent, 10 per cent, 15 per cent, etc., and burn the tests together at the same heat, and glaze them with the same glaze, we will notice that either no crazing, or at least but small cracks, appearing slowly, will be found on those tests which contain the least clay substance, and that the crazing increases in proportion, as the content of clay substance increases; that is, the cracks occur earlier, and the network which they form is closer woven.

From this, we come to the conclusion that by increasing the clay bonding material in a body, the expansion of the same with a rise in temperature is decreased. If we add in place of the Zettlitz kaolin, another binding material, which is more plastic, for instance the fat Mühlheim clay (containing 96 to 98 per cent of clay substance), we will arrive at the same conclusion, with this difference, that in tests of equal clay content those which contain the Zettlitz kaolin, craze worse in the glazing than those which contain the plastic clay. An addition of a plastic clay therefore decreases the coefficient of expansion, though in less degree than the less plastic kaolin clay.

If we leave the proportions of clay and quartz unaltered in the body, and increase the content of feldspar, burn the test pieces at the same temperature, and glaze them with the same glaze, we will find that the crazing occurs worst in those which are the highest in feldspar, and that it decreases gradually with the decrease of the feldspar. An increase of feldspar therefore acts also in the direction of reducing the expansion or contraction of the body of the ware.

Again, if we also increase the quartz content, using quartz powder of the same fineness which has been used in the previous tests, and carry on the burning and glazing as before, we will see that with the increase of the quartz, the network of crazing grows less and less, until finally the cracks disappear altogether. Now we see for the first time a weak "shivering" of the glaze on the corners and after a little, a deeper chipping of the body, and finally a complete demolition of the whole structure. Therefore, by raising the content of quartz, the coefficient of expansion of the body is raised.

Since in the preparation of a body, by grinding in a mill, it is generally the quartz which suffers a change in its size, for it only is really ground, while the clay is merely washed away in suspension, it seems of importance to know the influence which the sizing of the grains of the quartz may have on the body.

If we make a parallel set of tests, in such a manner that one contains the quartz of the same size as was used in the first series, and another contains an equal quantity of a coarser quartz, and another an equal proportion of the most extremely fine "floated" quartz, we observe, after an equally hard biscuit burn, that with the very fine-grained quartz, the crazing decreases with a less quantity of quartz, and the shivering begins earlier, than in the use of the coarser grained quartz.

With increasing quartz content, therefore, the coefficient of expansion will increase the more rapidly as the fineness of grain increases. Without altering the composition of the body, the behavior of the same glaze may be different, in respect to the phenomena dependent on the expansion by heat.

In every whiteware factory it is a well-known fact that the same glaze will be crazed on a piece of soft biscuit which, on a normal piece, would be fairly good, and also that cracking of the edges, and shivering of the decorated parts, takes place easier on very hard burnt biscuit, than on that which has been burnt to medium hardness in the biscuit fire. The coefficient of expansion will therefore be influenced also by the degree of vitrification which has been attained in the first, and generally the harder, burn in such a manner that it is increased with the increasing hardness of the burning.

The following means which may be deduced from the foregoing statements, are available in practical work for the counteraction of the defects of glazes which arise from the difference in contraction on cooling, always under the assumption that the composition of the glaze is to remain the same.

I. On the occurrence of crazing:
   A. Decreasing the content of the body in plastic bonding material, with simultaneous increase of the content of silica.
   B. Replacement of a part of the clay substance arising from kaolin, by that coming from plastic clays.
   C. Decrease in the content of feldspar.
   D. Finer grinding of the quartz content.
   E. Harder biscuit burning.

II. On the appearance of shivering of the glaze, or cracking of the edges of the ware, or the breaking off of attached parts (like handles and spouts, etc.):

A. Increase of the content of plastic clay substance with simultaneous decrease of the content of quartz.
B. Replacement of the clay substance arising from plastic clays by that arising from kaolins.
C. Increase in the content of feldspar.
D. Less fine grinding of the quartz.
E. Softer biscuit burns.

If we cause in a way similar to that which we have adopted in the consideration of the bodies, changes in the composition of the glaze, it will be possible to form an idea as to what will be necessary in any given case to bring the coefficient of expansion of the glaze into accord with that of the body.

Let us proceed in the same manner as we have done with the body and suppose that we have always the same body, and of a constant and uniform degree of hardness, and then produce systematic alterations of the glaze.

Let us start with the composition of a normal glass, which corresponds in its composition to a flint glass. The formula of the same can be expressed as follows:

$$0.5\ PbO,\ 0.5\ Na_2O,\ 2.5\ SiO_2.$$

If we leave the fluxes always constant, but proportion the silica in such a way that a series of glasses is produced whose compositions may be expressed by these formulas,

$$(0.5\ PbO,\ 0.5\ Na_2O,\ 2.0\ SiO_2),\ (0.5\ PbO,\ 0.5\ Na_2O,\ 2.1\ SiO_2),\ \text{etc., up to}\ (0.5\ PbO,\ 0.5\ Na_2O,\ 3.0\ SiO_2),$$

we will obtain glazes whose melting-point varies from cherry-red heat (600° C.) up to the melting-point of silver (960° C.). If these are burnt at temperatures suitable for their various melting-points, on pieces of ware of equal hardness, we will notice that, if any at all remain free from crazing, or show signs of shivering, it will be those which have the highest content of silica, and the network of cracks which arises will be more close-meshed, or the shivering will disappear and the glaze will adhere more perfectly, the lower the content of silica. We can draw from this the conclusion that the coefficient of expansion of the glaze decreases with the increase of the silica content and increases with the increase of the content of fluxes.

If we replace in the glaze, with which we started out, a part of the silica by boric acid according to equivalent proportions, and form thereby a series of glazes, whose formulas may be expressed by the following,

($0.5\,PbO$, $0.5\,Na_2O$, $2.4\,SiO_2$, $0.1\,B_2O_3$), ($0.5\,PbO$, $0.5\,Na_2O$, $2.3\,SiO_2$, $0.2\,B_2O_3$), etc., down to $2.0\,SiO_2$ and $0.5\,B_2O_3$,

we will find that these glazes become more easily fusible with the increasing content of boric acid, and that on bodies of uniform properties, if crazing occurs, it will be decreased by the increasing content of boric acid, in a very remarkable manner, and also if any shivering is noticed, that this characteristic grows worse with the increase of the boric acid.

It can, therefore, be deduced from the foregoing, that the introduction of boric acid into a glaze as a substitute for silica, decreases the coefficient of expansion.

If we make an alteration in the composition of the glaze with which we started out, and replace one flux by another, using in place of lead oxide, successively barium, lime, magnesia, potash, and soda, we will obtain a series of glazes, whose melting-points vary considerably from each other. The most fusible is the original lead oxide-soda glaze; then follow lead-potash, barium-soda, lime-soda, and lastly lead-magnesia. If we cover uniform pieces of ware with these glazes and burn them to a smooth glaze, we will notice that they do not behave alike by any means.[1] If in all or any of these, crazing ensues, the least tendency is manifested by the magnesia-soda glaze, and the strongest by the lead-soda glaze; the others will occupy intermediate positions between these extremes, as to the fineness of the network of cracks. If shivering ensues, it will be most strongly marked in the magnesia-soda glaze, and in the others it will decrease in the same order as has been indicated.

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[1] In order to compare the fusibility of different glazes, one can proceed as follows: Take a little copper or brass mold, made neatly from small pieces of sheet metal, soldered at the edges so as to produce small tetrahedra, each of whose sides is of equal length and, after oiling this mold, form from the different glazes by means of mucilage water, equally large cones, which are then fixed on a plate by dipping their bases in the gum and sticking them on. This plate is placed in a muffle, inclined at an angle of 45°, and the temperature raised till the most infusible glaze melts to a round button. The more easily fusible ones will have flowed down the inclined plate, and one can judge from the length of the path which they have made, which is the most easily fusible of the lot.

The percentage of the silica content increases through the introduction of the fluxes named, since their equivalent weight is smaller than that of lead. For example, that of the lead-soda glaze in question is 51.3 per cent, and that of the magnesia-soda glaze is 74.6 per cent, both being of the same stoichiometric composition. Thus is explained not only the noticeably increased infusibility of the magnesia-soda glaze, but also its slighter tendency towards crazing, and the increased tendency towards shivering, properties which, as we have seen befoıe, are both called into action by the increase of the content of a glaze in silica with a simultaneous decrease of the coefficient of expansion.

There remains now only to investigate the operation of the alumina, which in the more difficultly fusible glazes, plays a very important part. If one introduces into the glaze (0.5 PbO, 0.5 Na_2O, 2.5 SiO_2) successive portions of alumina of 0.1, 0.2, 0.3, of an equivalent, the melting-point of the glaze rises very rapidly, and at the same time the latter becomes cloudy and enamel-like.

Placed on the same body, on which the alumina-free glazes were crazed, it shows also crazing, and scarcely any difference can be distinguished in the fineness of the network of the cracks. The alumina content seems on this account to be without any noticeable influence on the expansion or contraction of glazes in temperature changes; this is especially illustrated in the ratio which the really active fluxes bear to the silica and the boric acid. The alumina takes a middle position in this connection, between the basic and the acid ingredients of the glaze.

From the statements now already laid down, we can draw the following conclusions for practical work. If the body is to be kept constant, then the glaze may be altered in the following ways:

1. On the occurrence of crazing:

A. By increase of the silica content, and decrease of the fluxes. This increase of the silica is limited, since its ratio to that of the fluxes must not exceed that of a trisilicate. If a further increase of the silica seems necessary, it can only be administered with a simultaneous introduction of alumina, in such a way, that through this increase of the alumina the acidity of the glaze remains always below the trisilicate ratio; otherwise, it shows a tendency toward devitrification. With an increase of the silica, and also the alumina content, an elevation of the melting-point of the glaze takes place.

B. By increase of the boric acid at the expense of the silica, leaving the other ingredients of the glaze unaltered. By this, a lowering of the melting-point of the glaze is accomplished.

C. By substitution of one of the fluxes with a high equivalent weight (and therefore a low percentage of silica) by one having a lower equivalent weight (and therefore a higher percentage of silica). An elevation of the melting-point of the glaze is coincident with this change.

2. On the occurrence of shivering, cracking of the edges, etc.:

A. By lowering the silica content, and at the same time increasing the content of fluxes. This reduction finds a limit, in the fact that the ratio between the silica and the fluxes must not fall below that of a bisilicate. If a glaze contains at the same time alumina, a reduction of the silica content can only be made below this ratio, when the alumina is simultaneously reduced. By this reduction the melting-point of the glaze is lowered.

B. By a decrease of the content of the boric acid, and corresponding gain to the silica content, leaving the other ingredients the same. By this means the melting-point is raised.

C. By the substitution of a flux having a low equivalent weight (for instance, lime or soda) by one having a high equivalent weight (for instance, lead or barium) and the consequent decrease of the silica percentage. By this means the melting-point of the glaze is reduced.

It is seen from the preceding facts that a series of remedies is at the disposal of the manufacturer whose wares show defects which arise from unequal coefficients of expansion for their counteraction. Which of these means he must use, whether one or several, will always depend on circumstances, especially on the degree in which the defects are present, and in how far he can move the limits inside of which he must remain as to the properties of the glaze and body.

But the preceding facts show how foolish is the endeavor among many manufacturers to obtain glaze receipts, which will have the property of showing on a certain ware neither crazes or shivering. There are no such glazes, for these are not the specific property of any special glaze, but the common expression of the composition of all glazes and bodies.

Only in rare cases will it happen that a glaze which fits a body in one place, will show the same qualities in another place, where different raw materials are used, and other differences of treatment occur. As a rule, this will not happen, as it depends on accident, and it ought to be the task of every manufacturer to take a definite glaze, and to systematically alter it until he has brought its coefficient of expansion into harmony with that of his body. One phenomenon, which has a bearing on the contraction of the body and glaze, and finds an easy solution in what has been said before, must receive attention at this time. It is a common occurrence to every producer of whiteware and porcelain, that one and the same glaze adheres free from crazing to the body after a long and hard glost fire, while after a short or softer firing, it becomes crazed; and further that the crazing becomes the worse, the thicker the layer of glaze.

This matter finds its explanation in the fact that the ingredients of the glaze do not work on each other alone, but also exert a chemical action on the substance of the body with which they come in contact. The glaze layer is always richer in fluxes than the body of the ware, and the last is richer in silica generally, and always richer in alumina than the glaze.

Chemical action on the body will, therefore, make a glaze richer in silica and alumina, and through this, as we have already seen, the ability to adhere without crazing is increased. The thinner the layer of glaze, and the longer the duration of the glost fire, and the higher temperature it attains, the more completely will this enriching of the glaze in silica and alumina from the ware take place, and if on account of thicker layers of the glaze this action should not permeate clear through its substance, it forms at least, immediately on the ware, a silicious transition layer, which is in position to mediate between the tension existing between the glaze and body.

IV. The Operation of Sulphates in the Glaze

It has previously been set forth that the presence of materials in the glaze such as are not taken up by glasses on fusion can hinder the production of a faultless glaze, because on the one hand, the temperature of glaze formation is never so high, as to permit the impurities to separate out as glass gall, and on the other hand, the thinness of the layer prevents materially the occurrence of such separations.

Among those materials which are capable of giving trouble in this connection, because they are either not absorbed at all, or not sufficiently absorbed by glasses, the sulphates and chlorides of the metals play an important part. Among the impurities which exist in the materials used in glazes, are those salts which contain a volatile acid, like carbonates, acetates, nitrates, etc., which are decomposed, those which contain non-volatile acids, like phosphoric acid which melt without influencing the brilliance of the glaze, together with those which like the sulphates and chlorides offer a greater resistance to absorption by the glass.

The sulphates, at least so the text-books say, are completely decomposed by silica, but this does not happen, at least not at those temperatures which come into consideration in the melting of glazes, and the other requirements which would cause a ready decomposition of the sulphates are never present. Chlorides are only decomposed in the presence of steam and then only at very high temperatures; common salt can be removed from the glaze or frit by sufficient leaching, but the sulphates generally form insoluble salts which cannot be leached out, like the sulphates of barium, lime and lead.

It is now well known from the researches of Pelouze on the making of glass, that sulphates can be dissolved in a glass without suffering decomposition thereby, and the content of sodium sulphate (which most resists decomposition) may even amount to 3 per cent of the whole weight of the glass. Such sulphate glasses have the property of efflorescing. These glasses, soon after exposure to the air, show a white deposit which can be easily washed off, but appears again in a few days, and spoils the surface of the glass. Very similar coatings can be seen on glazes which points to the fact that sulphates separate out from the glass, and if wiped away, appear again. Those glazes which contain potash show this property the most, and those which contain soda, the least.

A second and much more unpleasant manifestation occurring in glazes containing sulphuric acid, consist of a complete obscuring of the surface of the glaze, and a generation of bubbles in the glaze. Sulphates are less easily soluble in the more acid silicates than in the less acid ones, and since the glazes tend to take up silica from the body of the ware on which they are melted, and therefore to become more acid, it may easily occur that a part of the contained sulphates is expelled.

This is always accompanied by the generation of a gas, and remains noticeable in the glaze, because the layer of glass gall which forms simultaneously on the surface of the glaze, prevents the bursting of the bubbles. A coating thus forms on the surface of the glaze which, like the cream on milk, hinders the bursting of the bubbles and makes the glaze appear frothy.

If one were to melt in the same fire the two following glass batches,

$$BaO, SO_3 + 2Na_2O, CO_2 + 3SiO_2 + B_2O_3,$$

and

$$BaO, SO_3 + 2Na_2O, CO_2 + 5SiO_2 + B_2O_3,$$

he would obtain two layers in the crucible.

The lower layer would consist of an excellent clear glass, on which floats a crystalline streaky material, which dissolves in water, leaving a residue of silica. This upper layer consists mainly of sodium sulphate so that the decomposition must take place according to the reaction

$$BaO, SO_3 + 2Na_2O, CO_2 + n\ SiO_2 = BaO, Na_2O, n\ SiO_2 + Na_2O, SO_3 + 2CO_2.$$

The clear glass which is found under the cover of the sodium sulphate must be saturated, at the temperature at which it has been formed, with the sulphate. In fact, the first contained 4.50 per cent, and the second 2.10 per cent, of sulphuric acid. The first corresponds in its composition to a bisilicate, and the second to a trisilicate; both when melted on shards of ware, show not a glassy surface, but form a frothy mass, though they were previously melted perfectly clear.

The deduction from this experiment is that on the one hand the solubility of the sulphates decreases with the acidity of the glaze, and on the other hand that an expulsion of the sulphates takes place if the glaze has an opportunity to absorb silica. If we look around for the sources of these sulphates, we will find them readily enough, and even in the body of the ware itself. Clays often contain sulphates, which are soluble in water, and which effloresce on the corners and projections of the ware, but are made insoluble by the burning process.

Frequently the presence of sulphates in the clay can be detected by the colors imparted during the biscuit burn. Often when they are white they are not visible to the naked eye, but on examining them with a glass, they appear as little wart-like prominences. A second source of sulphates lies in the water which is used in making up the glaze. Hard water, and especially such holding calcium sulphate in solution, ought not to be used for these purposes. A third source of sulphates we find in the glaze materials themselves. The soda, borax, boracic acid, potash, and niter, intended for the frit fusion, often contain noticeable quantities of sulphates, and on this account ought to be carefully tested.

The more sulphates a glaze contains, or can absorb from the body, water, or glaze ingredients, the more it will be inclined to generate gases in the fire. We can in fact explain the evolution of gas in a glaze in no other way, than that the glaze contains some material which, under some conditions, will remain in combination, and under others will be set free and escape. In sulphuric acid we recognize such a material. It can occur in a glaze up to a certain amount, without affecting the brilliance of the glaze; but at a higher temperature, and when the absorption of silica begins, it separates from the glaze and forms a delicate skin on its surface, and hinders the bursting of the bubbles as they rise, formed simultaneously by the generation of sulphuric acid, or sulphurous acid, or oxygen.

The defects which a content of sulphates causes in a glaze are as follows:

It forms first a skin on the surface of the glaze, which often has a wrinkled appearance; this skin forms earlier on spots where the glaze is thin (and therefore has taken on an acid nature from the absorption of silica from the body) than where it is thick. Under this skin little bubbles assemble which do not burst, but which afterward break as soon as the glaze is touched by the hand. At the same time they will cut off, with their sharp edges, portions of the skin, and now appear no more as bubbles, but as black points or pits in the surface. Large bubbles form only where the glaze is thick. The phenomena, which are associated with the drying up of the glaze on the edge of plates, is probably due to sulphates in the glaze. As a rule, the glaze not only is thinner at the edge than elsewhere, but also the quantity of sulphates which have arisen from the body is generally greater there. The glaze has by no means been absorbed by the ware here more than elsewhere, and the piece looks dull, because there is on the surface of the glaze a layer of "gall," which makes it appear totally lacking in luster.

Sulphates do not always leave their traces in the glaze, in fact, only in the presence of oxidizing conditions of the kiln atmosphere; only then do these efflorescences occur which have been described. If the melting of the glaze is accompanied by a periodically reducing atmosphere, a reduction of the sulphates to sulphurous acid occurs readily, accompanied by the volatilization of the latter.

These phenomena, which are connected with the presence of sulphates in the glaze, do not appear when, during the melting of the glaze, a sufficiently reducing atmosphere has predominated in the kiln. From this property of the sulphate salts, it is easily understood why, in the porcelain industry, it is possible to use gypsum itself as a glaze ingredient as is done in many places.

Porcelain, when it is burnt under normal conditions, is burnt in a reducing fire. In this the sulphuric acid is completely volatilized at a temperature at which the glaze has not come into complete fusion, provided, the reducing fire is continued with sufficient length and intensity; the glaze under such conditions flows out smoothly.

But if the reducing flame does not develop with sufficient intensity, sulphuric acid will remain in the glaze, which is liberated gradually with the rising temperature, and produces the phenomena called "trichinae" or "scabby," that is, the glaze forms bubbles which do not burst in the fire, but subsequently when stroked with the hand, and become dark-colored by the filling up of the cavity with dirt.

V. THE CHARACTER OF THE BODY AND ITS RELATION TO THE GLAZE

Not only the chemical composition of the glaze exerts an influence on the properties of the same, but also the physical condition of the body and glaze. This fact is founded in the nature of the case. The reception of the glaze by the body generally takes place in such a way that the vessel to be glazed, after it has been more or less hard burnt, is dipped into the glaze which has been made up into a fluid mass. The layer of the glaze should form an even and homogeneous coating on the ware, without cracks, bare or dry spots, or holes. This requires that, on the one hand, the body must be homogeneous, for all inequalities will be marked by thick or thin spots in the glaze, and on the other hand, that the glaze shall possess the same property, in order that it shall not, on burning, form a cracked or wrinkled covering on the surface to be glazed.

In order to obtain a faultless glaze, it is above all things necessary that the body shall be free from air-holes and shall be homogeneous. Irregular bodies, which after burning contain softer and harder parts, absorb unequal quantities of the glaze slip, on the different portions. Porous bodies allow the air bubbles, which form when the glaze is applied, to escape unequally and produce a "pin-holed" glaze. Also, the degree of the biscuit burn has a great deal to do with the uniformity of the glaze layer. As a rule, bodies, which absorb water well, will also glaze well, though there is a limit to the operation of this statement. If the bodies are too soft burnt, or if they show a powdery, dusty surface, or if this dust is not thoroughly removed, they will take the glaze but poorly, and the glaze surface will show cracks on drying, or at the beginning of the burn; it rolls together and forms drops in one place and in another place it shows spots bare of glaze.

In porcelain another trouble comes as a consequence of too soft-burning in the biscuiting process which is called "pock-marking." The air escapes from the body with violence when it is dipped in the glaze slip, and if the body is too soft burnt, it may happen that the body is softened, or its internal cohesion overcome. Through this arise hollows, cracking and splitting of the body which, although not always noticeable, gives rise on burning to small prominences, owing to the fact that the air which is enclosed by the melting of the glaze expands in the heat.

If the glaze is to be carried by a raw clay (as is the case in the glazing of ordinary pottery, Bunzlau stoneware, etc.), the body must be in such a condition as best to endure the effect of the water on its surface. This is that condition known as "leather-hard," or "water-hard." If one attempted to put the glaze on the dry ware, the latter would, in consequence of the rapid absorption of water, be subjected to the danger of softening or swelling on the surface. In this case the deposition of the glaze layer does not occur from the absorption of the water by the body, but by the drying of a very thickly fluid slip on the surface.

If colors are used under the glaze, they often occasion defects, because they interfere with the adhesion of the glaze layer. Those colors especially act in this way, which are difficultly attacked by the glaze, and are infusible by themselves such as chrome oxide, cobalt-alumina oxide, pink, and others. Such colors form a separating layer between the glaze and the body, and hinder by their interposition, the necessary adhesion between the two. They occasion either a scaling off of the glaze, or a collecting together, or heaping up in single places (curdling). In such cases the mixing of the color with some glaze is the proper remedy in order to cause a fritting of the same.

It has already been said that the ingredients of the glaze must be applied in a finely ground condition to the surface of the ware. This is not done only to occasion an intimate mixture of the ingredients of the glaze, but also to permit an adhesion between them and the surface of the ware, for it is evident that the ingredients can only have the necessary adhesion after the water has been absorbed or evaporated from the surface of the ware, if they are sufficiently fine to secure a kind of interlacing or matting.

But one can go too far in this respect and introduce new troubles. The more a glaze is ground, the more water it takes up, and the more it becomes a sort of plastic substance. But the more plastic it is, the more it tends, on drying or on vitrifying, to crack, and there arise, through this, cracks or a scaling off of the glaze, or the glaze gathers together in spots and allows wrinkles or thick places to form. This defect occurs in direct proportion to the thickness of the layer of the glaze.

VI. Influence of the Fire on the Glaze

The action of the fire on the glaze does not begin with the moment at which the latter first alters its condition, but has already occurred long before this. Many alterations may occur in the early portion of the burn. In this part of the burn, steam condenses on the wares in those parts of the kiln which remain cool the longest.

With the use of mineral fuels, this steam or water smoke contains many foreign ingredients. It must be especially pointed out that the water of condensation from coal fires, is always acid, and contains free sulphurous, sulphuric, and hydrochloric acids. Naturally this fact is not without influence on the glaze. On the one hand, if it contains chalk, lead carbonate, lead oxide, or many other materials (basic), sulphuric acid will be introduced into its composition, which is followed by consequences of which warning has already been given; on the other, the colors which are used under the glaze layer are altered.

Colors are generally oxides, or oxide mixtures; they are attacked and dissolved by the acid water-smoke, and there are formed soluble salts from the chromium, cobalt, manganese, etc. These form, therefore, a colored spot around the original area, which becomes thereby bleached or paler in tint. The colors "spread," as it is called. With a strong condensation of water, these solutions, impregnated with the metallic salts, appear even on the other side of the vessel. This is called "striking through" of a color.

When the temperature rises higher, so that the water can no longer condense, many other phenomena take place. Metallic oxides which are in a condition to take up oxygen, forming non-basic peroxides, take it from the fire-gases only to give it up again, when the glaze has come into the fluid condition. This happens especially easily with the manganese and cobalt oxides. This absorption and expulsion of oxygen produces a bubbling of the glaze as a consequence. This not only happens when preparations containing these oxides are used as colors under the glaze, but also when they are previously fritted together with the glaze.

The bubbles arising from this cause are partly large, in which case they form, after bursting, round rings, and in part they are very small, forming what is called the "eggshell" structure. Chrome oxide used as a color, brings still another phenomenon into prominence. If the glaze is rich in alkalies and lead oxide, a part of the chrome oxide oxidizes and forms chromic acid. This is volatile to a noticeable degree, and gives to the surrounding parts of the glaze a yellowish color. This yellow coloration is transferred from one object to an adjacent one. When the temperature rises higher the gases from the fire begin to exert an influence on those glazes which contain lead. Under ordinary conditions, first the reducing gases, and then the oxygen, predominate in the kiln atmosphere; that is, a constant vacillation from oxidizing to reducing conditions takes place in the fire-gases.

When the gases are reducing in character, the lead oxide is converted into metallic lead, and under oxidizing conditions, the process takes a reverse course and the separated lead changes back into lead oxide. The glaze is colored black by this separation of metallic lead. When this separation of lead has once taken place, with its accompanying black coloration, it can only be overcome by a sufficiently long exposure of the glaze to free air, and often it remains permanent in spite of this treatment.

Blacked glazes form most easily in that stage of the burn in which the glaze begins to vitrify; each particle of the glaze is covered with a thin coating of metallic lead, which is fused into the glaze as the process goes on. A reduction thus takes place easily through the entire structure of the mass. Since the oxygen can only attack the surface, a dark coloration, produced as described, will change under the action of an oxidizing atmosphere only very slowly. This action is different in the glaze in which the pores have been closed from one which has not yet sintered together. In the latter the oxygen can penetrate from every side, and can reverse a previous reduction; in the glaze which has undergone fusion the reduction takes place only on the surface of the ware and penetrates only very slowly into the body of the mass, and therefore, it is very easily overcome by a subsequent oxidizing action of the fire-gases.

When the glaze has once come into full fusion the greatest danger of "smoking" it has passed. It is now affected only by a very intense and continuous exposure. It is even easy to produce a faultless white glaze with a "smoked" frit, if care is taken to expose it, in the early periods of the firing, to an atmosphere in which a sufficient quantity of oxygen is present, in order to carry back the lead, which has been reduced to the metallic condition, to the form of the oxide.

In glazes which do not contain lead a dark coloration of the surface through "smoking" may also take place; in this case it occurs from the deposition of a layer of carbon in the glaze; this can only occur when a very intense smoke is formed during the fritting stage of the glaze burn.

When the glost burn is interrupted too early the small uneven projectons which have arisen from the formation of bubbles and the bursting of the same, have not yet had time to smoothen; this fault has been called "egg shell" glaze from the similarity to the surface of an egg shell which the glaze presents. The egg shell glaze does not proceed only from too soft , but also from too hard burning, when the sulphates in the glaze cause an evolution of gases after the fusion of the glaze has once occurred. If isolated bubbles occur on the surface of the glaze, it is termed "spotted;" if the bubbles do not burst in the burn, but do so when they are stroked over by the hand, the glaze is then called "scaly." Both of these troubles are produced by the same cause.

One defect of glazes must in conclusion receive mention: this is the throwing or warping of the body of the ware due to the influence of the glaze. This takes place especially with flat objects, and very markedly on quadrilateral pieces or oval platters, which are glazed only on one side. These are often spherically bent, the glaze being found on the outer side of the piece. The explanation of this phenomenon is found in the fact that the glaze is still hard at a temperature at which the body has begun to vitrify and to shrink. That side of the plate carrying the glaze is kept from shrinking by this stiffness of the glaze, and therefore is held back in its shrinkage.

As a rule, the reason of this defect can be found in a too high alumina content of the glaze, which may be remedied accordingly.

A Discussion of Glazes with Special Reference to Whiteware Glazes Free from Lead

ALBERT BLEININGER, B.SC., TRANSLATOR

I. BODY AND GLAZE

In connection with a number of analyses of French whiteware bodies made some time ago, experiments were carried on intended to produce a body which is better suited for the manufacture of art-faience than the whiteware body obtainable in Berlin, and also to make possible the use of a glaze of a lower fusing-point, permitting a richer color scale for underglaze decoration. It seemed desirable to unite with this task a second one, namely, the replacement of the lead-glazes used hitherto by such free from lead. The use of glazes free from lead offers some decided advantages in the manufacture of art ware as well as of that intended for use.

The advantages of lead glazes consist in the ease of production, their fusibility and brilliancy. Their disadvantages are great softness, their tendency to become dim under the action of atmospheric influences and their great sensitiveness to reducing gases and corresponding ready change of the shades of colored glazes, and underglaze colors through the influence of fire-gases. To this is added that all lead preparations are strong, slow-acting poisons. Though this would not be of importance concerning the consumer of products having a well-fused and fritted glaze, as it alone finds application in the manufacture of whiteware, no lead being dissolved out of well-fused acid silicates by acids, yet the poisonous qualities of lead preparations cause the manufacturer many scruples on account of the injurious effects to which the workmen, employed in the making and application of the glaze, are seriously exposed. For this reason many experiments have been carried on by manufacturers of whiteware to replace lead in the glazes by other fluxes, but apparently without success up to the present, as far as very fusible glazes are concerned, as they are required for the production of fine whiteware. A few whiteware manufacturers produce glazes free from lead, but the attempts to introduce them generally have so far not been successful. Glazes free from lead are being applied, only to porcelain, stoneware and hard earthenware (Bunzlau ware) which are burned at a rather high temperature.

Of the oxides of the heavy metals there is to be considered, beside lead oxide, only zinc oxide as a flux, owing to its low price and its property of producing colorless glasses; however, it also, like the lead oxide, is poisonous, though in a less degree. Of the oxides of the alkaline earth metals three may be used as fluxes, barium oxide, lime, and magnesia; these also find application in the manufacture of glasses and are already being introduced in whiteware glazes, although only in combination with the alkalies, potash and soda, because it is known from the experience of the glass industry that lime-glasses entirely free from or low in alkali become milky and opaque on slow cooling. To these, alumina would have to be added as a flux, but always only in a limited measure, as it generally renders the glasses more difficult to fuse, and likewise opaque when used in large proportions.

As a substitute for the acid part of glazes (silicic acid), boracic acid is to be considered and it is indispensable in whiteware glazes, although its proportion is to be kept within the lowest limits possible,—on the one hand on account of the cost, and on the other hand, because the colors applied under the glaze are strongly attacked by it.

In the following experiments, beside the alkalies potash and soda, barium, lime, magnesia, and alumina were used as fluxes. Among these for the purpose of producing decorated pottery, barium was used first, because it, as has been proved by Benrath for the production of glasses, furnishes the most brilliant glasses and is the most powerful flux, and again because the colored glazes gain in brilliancy, in quite a remarkable manner, by a content of barium, and finally because with the assistance of barium glasses a series of beautiful colored glazes can be produced.

A content of alumina was avoided as much as possible in the production of the glazes and only employed for special purposes, as it diminished the beauty of the colors in the glazes under consideration.

A body and glaze from Choisy-le-roi served as the starting-point for the experiments, as these, among the whiteware materials obtainable, appeared to be those which first satisfied the conditions imposed.

Their composition was determined to be:

	Body.			Glaze.
	Total.	Insoluble in sulphuric acid.	Percentage composition of the matter insoluble in sulphuric acid.	Total.
Silica	67.45	43.24	45.56	49.20
Alumina	21.59	1.89	37.07	12.03
Ferric oxide	0.59	0.00	1.11	
Lime	0.00	0.00	0.00	4.41
Magnesia	0.51	0.00	0.99	trace
Potash	1.92	1.26	1.24	1.94
Soda	0.24	0.00	0.45	2.91
Water and carbon dioxide	7.23	0.00	13.60	3.28
Lead oxide	0.00	0.00	0.00	20.98
Boracic acid	0.00	0.00	0.00	5.25
Total	99.53	46.39		100.00

From this is calculated the body:

	Per cent.
Clay substance ($Al_2O_3\ 2SiO_2 + 2H_2O$)	53.61
Feldspar	9.73
Quartz powder	36.66

for the glaze the stoichiometric formula:

$$RO + 0.49\ Al_2O_3 + 3.47\ SiO_2 + 0.32\ B_2O_3.$$
$$RO = (K_2O,\ Na_2O,\ CaO,\ PbO).$$

It was next endeavored to produce from German raw materials a body and a glaze corresponding to the same composition.

For the body there was used:

Eberhahn clay, containing:

	Per cent.
Clay substance	86.0
Feldspar	trace
Quartz	14.0

Sennewitz kaolin, containing:

	Per cent.
Clay substance	65.0
Feldspar	trace
Quartz	35.0

also pure Norwegian feldspar and pure quartz sand, both finely ground.

From the analysis of the body from Choisy-le-roi the following composition is calculated, under the supposition that two-thirds of the clay substance is taken from the plastic clay, one-third from kaolin:

		Per cent.
B*a*.	Ebernhahn clay	41.6
	Sennewitz kaolin	27.5
	Quartz	21.2
	Feldspar	9.7
		100.00

The body was burnt so hard that it could not be scratched with a good steel blade, but showed a metallic streak, and was distinctly yellowish in color, therefore the content of kaolin was increased and the content of plastic clay correspondingly decreased, so that, maintaining the same composition, half of the clay substance was brought in by kaolin and half by the plastic clay. The body composition was thus:

		Per cent
B*b*.	Ebernhahn clay	31.6
	Sennewitz kaolin	41.2
	Quartz	17.6
	Feldspar	9.7

This body also was not sufficiently white, and hence the content of kaolin clay substance was increased to two-thirds of the total amount of clay substance. Thus the composition was as follows:

		Per cent.
B*c*.	Ebernhahn clay	20.8
	Sennewitz kaolin	55.0
	Quartz	14.5
	Feldspar	9.7

This body was sufficiently white and plastic, and served as the base for the first glaze experiments.

From the analysis of the glaze of Choisy-le-roi the following glaze composition is calculated:

	Per cent.
Feldspar	12.10
Sennewitz kaolin	38.85
Quartz sand	16.99
Marble	7.87
Lead oxide	21.49
Fused borax	8.16

The glaze produced from these materials proved stable on the whiteware body, which was made according to the composition of the Choisy-le-roi body. The temperature which is required to produce a good bright surface is that corresponding to the melting-point of gold.

As it was desirable to lower the fusing-point of the glaze, as well as to exclude the use of the lead oxide as a flux, introducing in its place the alkaline earths and alkalies, whose silicates of equal acidity are, as is known, more difficultly fusible than those of lead oxide, a number of glazes were compounded whose composition shows a less acid character than the glaze from Choisy-le-roi. The latter contains to one equivalent of basic fluxes (exclusive of alumina) nearly four equivalents of acid. The acidity of the first glazes made was in consideration of the desired low fusibility and corresponding to the composition of the ordinary glasses, for the most part taken between the bi- and trisilicates.

The burning of the glazes on the trial tiles, which were made out of the body B*c*, given above, and burnt up to a hardness (beginning bright white heat) at which they were yet porous but could not be scratched with a steel blade, was accomplished at silver-melting heat in a muffle fired with illuminating gas.

In order to determine the temperature exactly, a small plate of pure silver on a small clay saucer was set in the middle of the muffle in such a manner that it could be seen from the peephole. At the moment at which the little plate of silver collapsed into a drop the fire was extinguished.

In the accompanying table the composition of the glazes tested, as well as their behavior on the whiteware body, is given. The first row of the formulas shows the empirical formulas of the glaze, as they are computed from the components used, and the second expresses the ratio between base and acid. The numbers at the end, in parentheses, designate the ratio of silicic acid to the boracic acid in the acid part of the glazes.

As raw materials the following were used:

For potash,	feldspar or potassium nitrate,
For soda,	borax or sodium carbonate,
For lime,	marble or borate of lime,
For barium,	barium carbonate,
For alumina,	feldspar or kaolin,
For silica,	ground quartz,
For boracic acid,	borax, borate of lime or hydrous boric acid.

Although none of the leadless glazes tested would fit satisfactorily on account of crazing on the body (reproducing the Choisy-le-roi body) several remarkable phenomena, which made their appearance, led to the right track. It was shown throughout that the glazes high in fluxes whose degree of acidity approaches the bisilicate, commenced to craze during the cooling of the muffle and produced a close mesh of crazing. The acid glazes approaching the trisilicate, crazed only after complete cooling, sometimes only after several hours and produced a coarser net of crazes, while the still more acid glazes, between the tri- and tetrasilicate, showed occasional long cracks, partly only after a lapse of several days.

From this it becomes apparent that with a decrease of the quantity of flux the tension between glaze and body is lessened. The glazes high in alumina prove less inclined to crazing, than the ones free from alumina of equal degree of acidity; the alumina thus seems to behave similarly to silicic and boracic acid.

A strong tendency to devitrification is shown by the glazes

	Composition of glaze.	Character of glaze.
G	$2K_2O, Na_2O, 3CaO + 2Al_2O_3 + 16SiO_2 + 4B_2O_3$ $RO + 0.33Al_2O_3 + 3.33SiO_2$ (4 : 1).	Rough and crazed.
G 2	$2K_2O, Na_2O, 3CaO + 2Al_2O_3 + 18SiO_2 + 4B_2O_3$ $RO + 0.33Al_2O_3 + 3.66SiO_2$ (4.5 : 1).	Not bright; opaque and crazed.
G 3	$Na_2O, CaO + Al_2O_3 + 6SiO_2 + B_2O_3$ $RO + 0.5Al_2O_3 + 3.5SiO_2$ (6 : 1).	Milky; crazed.
G 4	$Na_2O, 2CaO + Al_2O_3 + 6SiO_2 + 2B_2O_3$ $RO + 0.33Al_2O_3 + 2.66SiO_2$ (3 : 1),	Milky; crazed.
G 5	$K_2O, 3CaO + Al_2O_3 + 10SiO_2 + 3B_2O_3$ $RO + 0.25Al_2O_3 + 3.25SiO_2$ (3.3 : 1).	Milky; crazed.
G 6	$K_2O, 4CaO + Al_2O_3 + 8SiO_2 + 4B_2O_3$ $RO + 0.2Al_2O_3 + 2.4SiO_2$ (2 : 1)	Milky; crazed.
G 7	$Na_2O, CaO, BaO + 7SiO_2 + 2B_2O_3$ $RO + 3SiO_2$ (3.5 : 1)	Devitrified and crazed.
G 8	$Na_2O, CaO, BaO + 5SiO_2 + 2B_2O_3$ $RO + 2SiO_2$ (2.5 : 1)	Brig't;badly craz'd; run strongly.
G 9	$2Na_2O, CaO, BaO + 12SiO_2 + 4B_2O_3$ $RO + 4SiO_2$ (3 : 1).	Crazed and devitrified.
G 10	$2Na_2O, CaO, BaO + 8SiO_2 + 4B_2O_3$ $RO + 4SiO_2$ (2 : 1).	Crazed;very bright; strongly run.
G 11	$2Na_2O, CaO, BaO + 6SiO_2 + 2B_2O_3$ $RO + 2SiO_2$ (3 : 1)	Very bright; run; badly crazed.
G 12	$2Na_2O, CaO, BaO + 8SiO_2 + 2B_2O_3$ $RO + 2.5SiO_2$ (4 : 1)	Very bright;crazed.
G 13	$2Na_2O, 2CaO, BaO + 8SiO_2 + 2B_2O_3$ $RO + 2SiO_2$ (4 : 1).	Very bright; badly crazed.
G 14	$2Na_2O, CaO, 2BaO + 8SiO_2 + 2B_2O_3$ $RO + 2SiO_2$ (4 : 1).	Very bright and liquid;badly crazed.
G 15	$2Na_2O, CaO, BaO + Al_2O_3 + 8SiO_2 + 2B_2O_3$ $RO + 0.25Al_2O_3 + 2.5SiO_2$ (4 : 1).	Very bright; crazed after a short time.
G 16	$Na_2O, CaO, BaO + Al_2O_3 + 6SiO_2 + B_2O_3$ $RO + 0.33Al_2O_3 + 2.33SiO_2$ (6 : 1).	Bright; crazed only after some hours.
G 17	$K_2O, 2Na_2O, CaO, 2BaO + Al_2O_3 + 14SiO_2 + 2B_2O_3$ $RO + 0.17Al_2O_3 + 2.66SiO_2$ (7 : 1)	Not quite bright; crazed after some hours.
G 18	$2K_2O, 2Na_2O, CaO, 2BaO + 2Al_2O_3 + 20SiO_2 + 2B_2O_3$ $RO + 0.25Al_2O_3 + 3.4SiO_2$ (10 : 1).	Bright only at the melting-point of 50 per cent gold, 50 per cent silver; crazed after several days.
G 19	$K_2O, Na_2O, CaO, BaO + 8SiO_2 + 2B_2O_3$ $RO + 2.5SiO_2$ (4 : 1).	Very bright; crazed immediately.
G 20	$K_2O, Na_2O, CaO, BaO + 10SiO_2 + 2B_2O_3$ $RO + 3SiO_2$ (5 : 1).	Very bright; crazed only after several hours.
G 21	$K_2O, Na_2O, CaO, BaO + 13SiO_2 + 3B_2O_3$ $RO + 4SiO_2$ (4.33 : 1).	Devitrified at edges; otherwise very bright; crazed on second day.

	Composition of glaze.	Character of glaze.
G 22	K_2O, Na_2O, CaO, BaO + $10.5SiO_2$ + $2.5B_2O_3$ RO + $3.25SiO_2$ (4.25 : 1).	Devitrified at the edges; crazed; quite bright.
G 23	K_2O, Na_2O, CaO, 2BaO + $13SiO_2$ + $3B_2O_3$ RO + $3.2SiO_2$ (4.33 : 1).	Devitrified at the edges; crazed; quite bright.
G 24	K_2O, Na_2O, 2CaO, 2BaO + $13SiO_2$ + $3B_2O_3$ RO + $2.66SiO_2$ (4.33 : 1).	Very bright; not devitrified, but stronger crazed.

free from alumina, whose acidity lies above the trisilicate, a phenomenon which has also been observed in the manufacture of glass. Small crystals identified under the microscope as needles arranged in star-like groups, segregate out on the surface, commencing at the edges; these deprive the glaze, on continued development, entirely of its gloss.

In glazes rich in alumina a similar tendency of dimming could be observed only when the heating above the fusing-point was continued for a long time, or when the test pieces were burned repeatedly.

In order to be able to fix for a given whiteware body a glaze adapted to it, or to produce a body for a glaze so that both may be combined without the glaze becoming crazed, or the body demolished by the contraction of the glaze, it seemed by all means necessary to fix the conditions, which must be complied with in order to give to the glaze and the body equal coefficients of expansion, without performing further empirical experiments, which so far had been unsuccessful. A direct measurement of the coefficient of expansion would require the use of very exact and expensive instruments and probably would not have led to a definite result. For this reason another way was pursued, namely, that of determining how the coefficient of expansion of the glaze as well as that of the body is increased or decreased by the fluctuations of the components. The glaze and the burnt body themselves serve as an index for the estimation of the influence, which a greater or smaller quantity of the glaze and the body materials exercises upon the variation of the coefficient of expansion.

The cause of the crazing and peeling off of glazes is that glasses and bodies attached to each other by the fusing of the former in the fire undergo, after cooling, different contractions. If the coefficient of expansion of the glaze is greater than that of the body, a tension ensues between both, which leads to a cracking of the glass in a vertical direction; the greater the difference in contraction is, the sooner and the more frequent must these cracks appear and the closer must become the mesh which they form.

If the coefficient of expansion of the glaze is less than that of the body, the latter exerts a pressure upon the layer of glaze after cooling, which effects a dislodging of the glaze, especially on surfaces curved towards the outside; in extreme cases this may cause the destruction of the body. Only when the difference between the coefficients of expansion is so slight that the tension produced does not exceed the limit of elasticity of glaze and body, is it safe to say that both will remain uninjured. But on changing the ingredients of glaze and body, when it is done systematically, it can easily be deduced from a narrowing or widening of the mesh of the crazing, whether the ideal condition of equal coefficients of expansion is approached or left.

In order to determine the influence of the ratio of silicic acid (and boracic acid) to the fluxes upon the coefficient of expansion of the glaze, the following nine glazes were applied to small tiles made from body B*c* previously mentioned, reproducing that from Choisy-le-roi; the first five were fused at silver-melting heat, and the last four, on account of their higher melting-point, at the fusing-point of an alloy of 80 parts of silver and 20 parts of gold.

The glazes have all the same ratio of silica and boracic acid; they differ from each other in the fact that the ratio of acid to flux increases one-fourth equivalent in each glaze. Of these glazes only those designated as G I and G IX were made directly into a clear glass by melting together the carbonates with quartz powder and hydrous boric acid; the others were produced by mixing these two in a finely powdered condition.

G I. K_2O, Na_2O, CaO, BaO + $6.4SiO_2$ + $1.6B_2O_3$ = RO, $2SiO_2$ (4:1)
G II. 7 equivalents G I + 1 equivalent G IX = RO,$2.25SiO_2$ (4:1)
G III. 6 equivalents G I + 2 equivalents G IX = RO,2.5 SiO_2 (4:1)
G IV. 5 equivalents G I + 3 equivalents G IX = RO,$2.75SiO_2$ (4:1)
G V. 4 equivalents G I + 4 equivalents G IX = RO,$3.00SiO_2$ (4:1)
G VI. 3 equivalents G I + 5 equivalents G IX = RO,$3.25SiO_2$ (4:1)
G VII. 2 equivalents G I + 6 equivalents G IX = RO,$3.50SiO_2$ (4:1)
G VIII. 1 equivalent G I + 7 equivalents G IX = RO,$3.75SiO_2$ (4:1)
G IX. K_2O, Na_2O, CaO, BaO + $12.8SiO_2$ + $3.2B_2O_3$ = RO, $4SiO_2$ (4:1).

All these glazes showed excellent gloss; the first ones had strongly run, thus having been in the thin fluid condition, G I the most; the last ones had run off little or none, but had a tendency to devitrification, G IX most strongly. The first ones were already completely crazed on taking out of the muffle (at a temperature between 50° and 100° C.); with the others, crazing appeared only after a couple of days and after the glaze surface had been scratched with a file. After eight days the cracks with G I were so fine that the mesh could hardly be followed with the naked eye; with G IX a very wide mesh of crazing was shown by a few long cracks. With the intermediate glazes the mesh formed by the crazing was the wider, the nearer they approached the composition of G IX, and the closer the nearer G I.

From this it appears that with the increase of the fluxes in the glaze its coefficient of expansion increases; the tendency to crazing thus increases, but decreases with an increase in the content of acid (*silicic and boracic acid*).

This means, applied to practice, that, if a glaze crazes, its fusing-point must be raised by decreasing the fluxes or increasing the silicic and boracic acid content in order to remove the crazing.

The addition of boracic acid to the whiteware glazes as a substitute for silicic acid has the purpose, on the one hand, of lowering their fusing-point, without being obliged to increase the quantity of the fluxes for the same purpose, which would cause them to become softer and more easily scratched; on the other hand, it increases their gloss and the brilliancy of the colors. On account of the increased cost of the glaze caused by the addition of boracic acid, it will be necessary to keep the latter within moderate limits. This applies especially to decorated products, carrying underglaze colors, since these, in glazes high in boracic acid, are easily dissolved by the fusing glass, and more than is desired.

The rôle, which the boracic acid exercises in regard to stability of a glaze, proceeds from the following experimental series:

G X. K_2O, Na_2O, CaO, BaO + $9.6SiO_2 + 2.4B_2O_3$
$RO + 3SiO_2$ (4:1).
G XI. K_2O, Na_2O, CaO, BaO + $10.0SiO_2 + 2\ B_2O_3$
$RO + 3SiO_2$ (5:1).
G XII. K_2O, Na_2O, CaO, BaO + $10.3SiO_2 + 1.7B_2O_3$
$RO + 3SiO_2$ (6:1).

Accordingly, the three glazes possessed the same ratio between acids and bases; they only differed in the content of boracic acid, which was introduced as a substitute for silicic acid.

On the whiteware body B*c*, given above, all the glazes crazed, though not to an equal degree. The glaze G X, highest in boracic acid, showed the widest, G XII the narrowest, mesh; the crazes on G XII appeared directly after the cooling of the trial piece, on G X on the next day, and on G XI after several hours.

From this it follows, that the coefficient of expansion of the glaze decreases with an increase of the boracic acid content and more decidedly than with an increase of the silicic acid, and that thus the crazing of a glaze can be lessened or stopped by an increase of the boracic acid content or by a more extensive substitution of silicic by boracic acid.

The influence which a content of alumina exercises was determined by the following experimental series:

Glaze G I was compounded with such quantities of pure alumina, obtained by igniting precipitated aluminum hydrate, that the composition was:

G XIII. K_2O, Na_2O, CaO, BaO, $Al_2O_3 + 6.4SiO_2 + 1.6B_2O_3$
$RO + 0.25Al_2O_3 + 2\ SiO_2$ (4:1).
G XIV. K_2O, Na_2O, CaO, BaO, $2Al_2O_3 + 6.4SiO_2 + 1.6B_2O_3$
$RO + 0.5Al_2O_3 + 2SiO_2$ (4:1).
G XV. K_2O, Na_2O, CaO, BaO, $3Al_2O_3 + 6.4SiO_2 + 1.6B_2O_3$
$RO + 0.75Al_2O_3 + 2SiO_2$ (4:1).

The glaze XIII became perfectly bright and transparent only at the temperature of the fusing-point of an alloy of 50 per cent of silver, 50 per cent of gold; XIV was not transparent but dull at gold fusing heat; XV showed hardly any gloss and had the appearance of an imperfectly fused enamel.

On cooling, all the glazes crazed at once, forming a fine mesh, as fine as that of the glaze G I free from alumina. According to this, the content of alumina is without important influence upon the coefficient of expansion of the glaze; it operates favorably in an indirect way inasmuch as it permits the raising of the silicic acid content, without causing the glaze to become dim on long-continued melting.

What influence is exercised by the different fluxes (potash, soda, lime, magnesia, lead oxide) is shown by the following experiments:

In the glaze G V

$$K_2O,\ Na_2O,\ CaO,\ BaO + 9.6SiO_2 + 2.4B_2O_3$$
$$RO,\ 3SiO_2\ (4:1),$$

for the one molecule of barium there was substituted another flux and thus the following glaze compositions were obtained, in each of which one of the four fluxes predominates.

G XVI. $2K_2O,\ Na_2O,\ CaO + 9.6SiO_2 + 2.4B_2O_3$
$RO,\ 2SiO_2\ (4:1)$.
G XVII. $K_2O,\ 2Na_2O,\ CaO + 9.6SiO_2 + 2.4B_2O_3$
$RO,\ 3SiO_2\ (4:1)$.
G XVII. $K_2O,\ Na_2O,\ 2CaO + 9.6SiO_2 + 2.4B_2O_3$
$RO,\ 3SiO_2\ (4:1)$.
G XVIII. $K_2O,\ Na_2O,\ 2BaO + 9.6SiO_2 + 2.4B_2O_3$
$RO,\ 3SiO_2\ (4:1)$.
G XIX. $K_2O,\ Na_2O,\ CaO,\ MgO + 9.6SiO_2 + 2.4B_2O_3$
$RO,\ 3SiO_2\ (4:1)$.
G XX. $K_2O,\ Na_2O,\ CaO,\ PbO + 9.6SiO_2 + 2.4B_2O_3$
$RO,\ 3SiO_2\ (4:1)$.

The glazes fused on to the tiles at the same heat, had nearly equal brilliancy, but showed an unlike behavior in regard to the degree of crazing. The lead glaze G XX had crazed most, having the closest mesh; next came the barium glaze G XVII. The potassium and sodium glazes stood about equal, then followed the lime, and lastly the magnesia glaze.

This succession stands in relation to the equivalent values of the predominating fluxes of the glazes, as lead oxide appears in them with the highest number, 111.5, magnesia with the lowest, 20. But the percentage content of silica in the glazes decreases with the rising equivalent weights of the fluxes, so that the lead glaze shows the lowest, the magnesia glaze the highest, content of silicic acid.

These changes in the composition must also be expressed in the fusing-point of the glazes. In order to determine the relative fusibility of the glazes the following method was followed: From the glazes G XVI to G XX small tetrahedra 22 mm. high were made in a copper mold by kneading the glaze with mucilage water. These cones were fastened to a clay plate over a lead-pencil line by moistening with a drop of water. The clay tile was set into the muffle in such a manner that it was inclined at an angle of 45°, and the glaze cones were placed along a horizontal line. The fusibility was determined according to the length of the path which the glazes at the melting-point of silver had traced on running down. The glaze drops of the lead glaze described the longest path, 6 cm.; the barium had flown 3 cm., the glazes with potash, soda and lime had run only little, ½ to 1 cm. below the lead-pencil line; the magnesia glaze cone had drawn together to a round drop without flowing.

From this it follows that with analogous stoichiometric composition the glazes craze the easier, *their coefficient of expansion being the greater*, *the more fusible they are*, *that is*, *the greater the equivalent weight of the fluxes.*

In regard to the adhesion of a glaze not only its composition is of importance, but also the composition of the body, for it is known that a glaze, proving stable on a certain body, might craze on another, or again it might shiver. Even the degree of burning which the whiteware body received, is of great influence; hence, in order to throw light on these conditions, we must examine the influence of the body composition and the intensity of burning on using the same glaze.

For the composition of the body the following points come into consideration:

1. Its content of cementing bonding material, the clay substance.
2. The degree of plasticity of the clay substance.
3. The content of feldspar.
4. The content of quartz.
5. The degree of fineness of the quartz.
6. The degree of burning which the body received.

In order to determine the influence of the first five points upon the stability of the glaze, the following series of experiments were carried out. Bodies were produced:

A. From quartz with plastic clay substance (derived from Ebernhahn clay) with a quartz content of 50 to 90 per cent, rising in intervals of 5 per cent.

B. From quartz with plastic and kaolin clay substance (Ebernhahn clay and Sennewitz kaolin), with a constant content of plastic clay substance (20 per cent), a rising content of kaolin clay substance (5 to 40 per cent), and with a simultaneously decreasing content of quartz (75 to 40 per cent).

C. With a constant content of plastic clay substance (25 per cent), a decreasing content of quartz (from 70 to 35 per cent), and at the same time an increasing feldspar content.

D. With constant content of plastic clay substance (40 per cent) and quartz (60 per cent), the latter, however, with increasing coarser grinding.

From the bodies tiles were made and this series burnt in one firing so hard that they could not be scratched with a penknife, the steel leaving but a black streak. They were covered with the following glazes and those having the same glazes were burnt in the same muffle.

1. Lead glaze, K_2O, Na_2O, CaO, PbO, $9.6SiO_2$, $2.4B_2O_3$
   $RO, 3SiO_2$ (4 : 1).
2. Barium glaze, K_2O, Na_2O, CaO, $9.6SiO_2$, $2.4B_2O_3$
   $RO, 3SiO_2$ (4 : 1).
3. Lime glaze, K_2O, Na_2O, $2CaO$, $9.6SiO_2$, $2.4B_2O_3$
   $RO, 3SiO_2$ (4 : 1).
4. Magnesia glaze, K_2O. Na_2O, CaO, MgO, $9.6SiO_2$, $2.4B_2O_3$
   $RO, 3SiO_2$ (4 : 1).
5. Alumina barium glaze, K_2O, Na_2O, CaO, BaO, $0.1Al_2O_3 + 13.6SiO_2$, $2.4B_2O_3$
   $RO, 0.1Al_2O_3, 4SiO_2$ (5.66 : 1).

The burning temperature of the last glaze is close to the melting-point of gold; the others became bright at the fusing-point of silver.

In the following table the composition of the whiteware bodies is given as well as their behavior in regard to the above glazes. The trials on which crazing appeared within a month are marked with a cross, those which showed shivering at the edges with O, and on those not marked the glazes proved stable.

A. BODIES CONSISTING OF QUARTZ AND PLASTIC CLAY SUBSTANCE

Composition of body.	1	2	3	4	5	6	7	8
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Quartz - - -	90	80	75	70	65	60	55	50
Clay substance - -	10	20	25	30	35	40	45	50
Lead glaze - -	O	O			×	×	×	×
Barium glaze - -	O	O					×	×
Lime glaze - -	O	O					×	×
Magnesia glaze - -	O	O					×	×
Alumina barium glaze	O	O	O					

B. BODIES CONSISTING OF QUARTZ, PLASTIC AND KAOLIN CLAY SUBSTANCE

Composition of body.	1	2	3	4	5	6	7	8
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Plastic clay substance	20	20	20	20	20	20	20	20
Kaolin clay substance	5	10	15	20	25	30	35	40
Quartz - - -	75	70	65	60	55	50	45	40
Lead glaze - -		×	×	×	×	×	×	×
Barium glaze -				×	×	×	×	×
Lime glaze - -				×	×	×	×	×
Magnesia glaze -					×	×	×	×
Alumina barium glaze	O	O	O	O				

C. BODIES CONSISTING OF QUARTZ, FELDSPAR AND PLASTIC CLAY SUBSTANCE

Composition of body.	1 Per cent.	2 Per cent.	3 Per cent.	4 Per cent.	5 Per cent.	6 Per cent.	7 Per cent.	8 Per cent.
Plastic clay substance	25	25	25	25	25	25	25	25
Quartz	70	65	60	55	50	45	40	35
Feldspar	5	10	15	20	25	30	35	40
Lead glaze			×	×	×	×	×	×
Barium glaze			×	×	×	×	×	×
Lime glaze			×	×	×	×	×	×
Magnesia glaze						×	×	×
Alumina barium glaze								

D. BODIES CONSISTING OF PLASTIC CLAY SUBSTANCE AND QUARTZ OF DIFFERENT GRAIN

Composition of body.	1 Per cent.	2 Per cent.	3 Per cent.	4 Per cent.	5 Per cent.	6 Per cent.	7 Per cent.
Plastic clay substance	40	40	40	40	40	40	40
Quartz sand 6 hours in mill	60	50	40	30	20	10	0
Quartz sand 90 minutes in mill	0	10	20	30	40	50	60
Barium glaze		×	×	×	×	×	×
Alumina barium glaze			×	×	×	×	×

In reference to the behavior of the body with different degrees of burning special experiments were not made, as it is known that in using one and the same glaze, too soft a burn leads to crazing, too hard a one to shivering of the glaze.

It will be observed from the preceding tables, that glaze defects become noticeable in all cases from a fixed limit on, and that in order to obtain stable glazes, only slight room for the variation in composition of the whiteware body is admissible. There is shown throughout that crazing and shivering of the glaze appear the sooner, and in the first case the mesh of the crazes becomes the narrower, the farther the composition diverges from the admissible one.

It is further concluded that the room for variation admissible in the composition of the body is the less, the more fusible the glaze is, and the greater the more difficultly fusible it is. The effects of the separate constituents present in the body of the whiteware can now be collected as follows:

The content of quartz counteracts the crazing, but assists the shivering of the glaze, the more (the coefficient of expansion of the body being increased the more) the greater its quantity and the finer its grinding.

The content of clay substance increases the crazing and prevents shivering (the coefficient of expansion being decreased), and increases the more as it possesses the physical properties of the kaolin clay substance (the looser it dries).

The content of feldspar assists crazing and counteracts shivering, the more the greater its amount.

Although from the preceding observations the composition of a glaze correctly adapted to a certain body cannot be developed by calculation, yet the results permit the application, if glaze defects appear, of a number of remedies.

If a glaze crazes on a given body, the following means may be used to remove the defect:

A. By altering the body, maintaining the same composition of the glaze:

1. Harder burning of the body.
2. Finer grinding of the quartz.
3. Decrease of the clay substance and simultaneous increase of the quartz content.
4. Increase of the plastic clay substance at the expense of the kaolin clay substance, maintaining the same total quantity of clay substance.
5. Decreasing the feldspar content at the expense of the content of quartz or clay substance.

If the glaze shivers, these alterations are, of course, to be reversed.

B. By altering the composition of the glaze, maintaining the same body:

1. Raising the melting point of the glaze by the addition of sand, feldspar, or clay substance.
2. Increasing the content of boracic acid at the expense of the silica content, keeping the acid proportion constant.
3. Substitution of the fluxes with higher, by such with lower, equivalent weights.

If the glaze shivers, the contrary alterations are to be made. If a glaze inclines to dimming, it is to be altered :

1. By making it more fusible, by increasing the amount of fluxes or the boracic acid content.
2. By introducing alumina as an ingredient, or by increasing the alumina content.

It is not difficult to find for every glaze a suitable body and for every body a suitable glaze, by considering the relations laid down, by means of a comparatively small number of practical experiments. Thus it will also be possible to substitute by calculation one clay by another, if by analysis their content of clay substance, undecomposed feldspar and quartz sand is determined.

For practical purposes a difficulty is met only in so far as the quartz sand naturally present in the different clays, does not always possess the same degree of fineness, even when very fine sieves have been used in washing. As the washing in the preparation of whiteware bodies must always be accomplished with the use of the finest metal wire sieves it is possible to make, as a rule, with sieves of 30 to 50 wires per linear centimeter, the size of grain of the quartz, below the limit drawn by the sieves, escape all discrimination.

On changing the grain of the powdered quartz in the clays the body composition found by calculation must be corrected according to a practical test.

For example, if a clay is replaced by another, in which the quartz sand is contained in a coarser grained condition, on application of the same glaze crazing will appear, if the same proportion of clay substance, quartz and feldspar is maintained ; hence the content of clay substance of the composition is to be lowered and that of quartz raised.

On the other hand shivering may appear in the same composition of the body, if the clay introduced as a substitute contains the quartz powder in a finer state of division than the one used before; in order to remove the defect the content of clay substance must be raised, and that of quartz lowered.

As a foundation for the subsequent experimental work involving whiteware bodies, and which was conducted on a larger scale, according to the previous fundamental investigations, a body was used of the following composition:

	Per cent.
Clay substance	35
Quartz	65

For the supply of clay substance there served the Ebernhahn clay (containing 76 per cent of clay substance and 24 per cent quartz) and Sennewitz kaolin (containing 65 per cent clay substance and 35 per cent quartz) and there was introduced 20 per cent of the clay substance from this plastic clay, 15 per cent from the kaolin.

From this is computed the body composition:

	Per cent.	
Clay from Ebernhahn	26	Whiteware body No. 1
Kaolin from Sennewitz	23	
Finely ground quartz	51	

As a glaze for the body there was used the one previously designated as G V of the composition

$$K_2O, Na_2O, CaO, BaO + 9.6SiO_2 + 2.4B_2O_3$$

$$RO, 3SiO_2 \ (4 : 1),$$

obtained by fusing together:

	Per cent.	
Potassium nitrate	101.0	Colorless whiteware glaze G V
Marble	50.0	
Barium carbonate	98.5	
Crystallized borax	191.0	
Crystallized boracic acid	24.8	
Quartz sand	288.0	
	753.3	= 554.5 fused glaze.

In the course of further work this whiteware body offered many difficulties; it was brittle and sensitive to a somewhat sudden change of temperature and carried the glaze well only within a fixed narrow limit of burning within which it was difficult to keep. When the body was burned too soft, so that it could be scratched with a hard steel blade, the glaze crazed after some time ; when it was burned so hard that it was only slightly absorbent the glaze readily shivered at the edges of the ware.

Hence, body I was blended with 10 per cent of feldspar.

This gives the composition :

	Per cent.	
Ebernhahn clay	26	Whiteware body No. II
Sennewitz kaolin	23	
Quartz	51	
Feldspar	10	
	110	

This body also was equally unsatisfactory, as the glaze crazed even on hard burning and became stable only when the body was burned so dense that it absorbed the water of the glaze but slightly.

For this reason the content of feldspar was lowered again and a body selected of the following composition :

	Per cent.
Clay substance	35
Quartz	60
Feldspar	5
	100

corresponding to the body composition :

	Per cent	
Ebernhahn clay	26	Whiteware body No. III*a*.
Sennewitz kaolin	23	
Quartz	46	
Feldspar	5	
	100	

The body was satisfactory in regard to its behavior toward the glaze, but showed a certain brittleness, and in the biscuit burn, especially in the case of large flat pieces, a large breakage occurred (up to 50 per cent). This breakage, however, was avoided by substitution of the Ebernhahn stoneware clay by one from Grossalmerode (plastic clay from Gundlach Brothers), so that in the future no breakage worth mentioning occurred in the biscuit burn.

The Grossalmerode clay contains:

	Per cent.
Clay substance	89
Quartz	9
Feldspar	2

From this the following body composition is computed:

	Per cent.	
Clay from Grossalmerode	89	Whiteware body No. III*b*.
Kaolin from Sennewitz	23	
Quartz	51	
Feldspar	5	
	100	

For the production of colored whiteware bodies, in place of the white burning clays from Ebernhahn, Grossalmerode and Sennewitz, raw materials, colored by a natural content of iron oxide, were used.

The composition of these red burning clays is as follows:

	Clay from Moschheim Per cent.	Clay from Helmstaedt. Per cent.
Clay substance ($+Fe_2O_3$)	76.68	78.35
Quartz and slight quantities of feldspar	23.32	21.65

Thus for a body of 35 per cent clay substance and 65 per cent of quartz, the following composition results:

Moschheim clay	45.5	or	Helmstaedt clay	44.5	Red whiteware body.
Ground quartz sand	54.5		Ground quartz sand	55.5	

Both bodies when burnt at about gold-melting heat possessed a beautiful dark red color. The previously mentioned whiteware glaze G V proved perfectly stable and did not materially change the color of the clay, only deepening it somewhat.

For the production of a yellow whiteware body materials were likewise used which assume in the fire a yellowish green color, owing to a natural content of iron, and there were used a lean glass pot clay from Gundlach Bros. at Grossalmerode:

	Per cent.
Clay substance	44.04
Quartz	53.43
Feldspar	2.53

and a clayey molding sand from H. Haltern at Heinberg:

	Per cent.
Clay substance	20.03
Feldspar	14.10
Quartz	65.87

As the molding sand was apparently coarser grained than the ground quartz sand used for the whiteware body, the content of clay substance in the body had to be lowered, and the following mixture was selected for the composition of the body:

	Per cent.
Clay substance	20
Feldspar	5
Quartz sand	75

The following body mixture is now computed:

	Per cent.	
Lean glass pot clay from Grossalmerode	45	Yellow whiteware body.
Molding sand from Steinberg	55	

The body showed a light buff color when burnt hard, and carried the glaze G V previously mentioned free from crazing. With too hard a burn, the porosity of the body being nearly destroyed, the glazes shivered along the edges.

For some purposes, especially for the production of larger tiles, it seemed desirable to make for the same glaze a grog body, which is less liable to warping and cracking on drying and burning, than the finer whiteware body, and which can also be produced cheaper than the latter. It seemed most expedient to select conditions such that the composition of the grog and that of the bonding clay equalize each other, so that about the same proportion between clay substance and quartz exists, as in the whiteware body No. 1, which proved suitable with the right degree of burning.

The saggar clay, from which the grog was made, Salzmuend clay, had the following composition:

	Per cent.
Clay substance	49.33
Quartz	49.86
Feldspar	0.79
	100.00

It is lower in quartz than was required for the glaze used; hence the clayey bonding material was taken higher in quartz.

First the following proportions were selected:

	Parts.
Grog powder, through a sieve of 10 meshes per linear cm.	50
Finely ground quartz sand	9
Lean clay from Grossalmerode	41
	100

The grog body proved unsuitable for the glaze G V; the glaze shivered strongly, hence the quartz sand content had to be lowered.

But a good result was obtained by:

	Parts.	
Grog powder through a sieve of 10 meshes per linear cm.	50	Grog body.
Lean clay from Grossalmerode	50	

II. Colored Glazes

So far colored glazes for the decoration of whiteware are being produced, as a rule, by dissolving metallic oxides or their mixtures and compounds which serve as underglaze colors in the colorless whiteware glaze. If the glazes are to be strongly colored, the quantity of metallic oxide thus being considerable, the fusibility of the glaze as well as its stability on the body will be materially affected by this condition.

In order to reduce the entire color scale of colored glazes to one melting temperature, which is necessary by all means, if it is intended to accomplish their application in a single firing, corrections must be made, which are determined by empirical experiments. According to whether the addition of coloring metallic oxides or their compounds renders the colorless glaze more or less fusible, the equalization must be accomplished sometimes by lowering, sometimes by raising, the content of basic fluxes.

But in practice weighty difficulties are in the way of an adjustment, thus accomplished, of the colored glazes, for even if the glazes are brought to a uniform melting-point, we are not certain that they, without exception, will adhere to a certain whiteware body without crazing.

On the contrary we observe in all work carried out with colored glazes, that part of the glazes are free from crazing, but that others are crazed; some glazes again are more fusible than others.

This observation led to an attempt to try the production of colored glazes by another way altogether than is being generally followed at present, and this was suggested after the mutual relations of the glaze constituents and their influence upon the fusibility and stability of the glazes had been determined. While according to the method hitherto followed, all colored glazes necessarily received a different chemical constitution, it was tried to impart to them a uniform composition, not by dissolving fluctuating quantities of metallic oxides in the colorless glaze, but by the substitution of a part of the fluxes by the coloring metallic oxides, which are also fluxes. In order to obtain the colored glazes without material alteration in their fusibility in lighter or deeper shades, to be able to mix them in any way and to dilute them with colorless glaze, all the glazes (with the exception of those which contain the noble metals as coloring ingredients) were given a uniform composition, coinciding with that of the colorless glaze G V. For this purpose very strongly colored glaze frits were produced by leaving out half of the fluxes in glaze G V, and introducing in their place an equivalent quantity of the coloring metals in the form of oxides.

For the production of colored glazes the following metals come into consideration by virtue of their coloring power and their cost: Iron, manganese, nickel, cobalt, chromium, uranium, copper, gold, platinum, iridium.

The three last ones are not coloring pigments in the sense of the preceding ones, because they are not soluble in the fusing glaze, but are suspended in it in the metallic state in a finely divided condition and possess a strong coloring power even in extremely small quantities.

If R stands for any of the coloring metals, the stoichiometric formula of the colored glaze frits is as follows:

$$\left.\begin{array}{c} 0.5K_2O,\ 0.5Na_2O,\ 0.5CaO,\ 0.5BaO \\ 2RO \text{ or } R_2O_3 \end{array}\right\} + 9.6SiO_2,\ 2.4B_2O_3.$$

These were obtained by melting together:

	Per cent.
Potassium nitrate	50.5
Marble	25.0
Barium carbonate	49.2
Crystallized borax	95.5
Crystallized boracic acid	86.8
Sand	288.0
Coloring metallic oxide	*n*

n is equal to:

For the iron frit,	80.0 Fe_2O_3.
For the manganese frit,	76.4 Mn_3O_4.
For the nickel frit,	74.8 NiO.
For the cobalt frit,	80.4 Co_3O_4.
For the chromium frit,	76.2 Cr_2O_3.
For the uranium frit,	141.3 U_3O_4.
For the copper frit,	79.4 CuO.

For a glaze containing gold, 1 part of gold in the form of Cassius purple was introduced into 1000 parts of colorless whiteware glaze;

For a glaze containing platinum, 1 per cent of platinum as ammonium platinic chloride;

For a glaze containing iridium, 1 per cent of iridium sesquioxide.

The colors which the barium glazes, free from lead, assume due to their content of coloring metallic oxides, vary in many ways from those, which the ordinary lead-alumina whiteware glazes show under similar conditions. This is especially noticeable in those glazes which contain the oxides of manganese, nickel and copper. The oxides of manganese give a violet-brown, the oxide of nickel a grayish brown, the oxide of copper a light blue color, while the ordinary lead whiteware glazes produce under similar conditions reddish brown, yellowish brown and green. The copper oxide especially furnishes on strong dilution beautiful sky-blue and turquois-blue glazes.

The colored glaze frits which contain about 15 per cent of coloring metallic oxides, the one containing uranium even 23.7 per cent, cannot be used as colored glazes, because when fusing they readily show surface segregations with metallic reflection.

They must always be diluted with a colorless glaze. For the more intense colors they are diluted with an equal quantity of glaze by weight. The colors which the glaze frits assume on dilution are as follows:

Iron frit : Colorless glaze.
1 part : 1 part, by weight, brownish yellow.
1 part : 3 parts, ivory-yellow.
1 part : 5 parts, ivory-yellow.
1 part : 10 parts, nearly colorless, only noticeable in thick layers.
Manganese frit : Colorless glaze.
1 part : 1 part, dark violet-brown.
1 part : 3 parts, violet-brown.
1 part : 5 parts, violet.
1 part : 10 parts, bright violet.

The colors are noticeable up to a very strong dilution.

Nickel frit : Colorless glaze.
1 part : 1 part, blackish brown.
1 part : 3 parts, dark grayish brown.
1 part : 5–10 parts, light grayish brown.

Color noticeable up to a very strong dilution.

Cobalt frit : Colorless glaze.
1 part : 1–10 parts, dark blue,

corresponding to the content of cobalt, grayish blue in lamp light.

Noticeable up to a very strong dilution.

Chromium frit : Colorless glaze.
1 part : 1–5 parts, green, opaque.
1 part : 10 parts, green, somewhat transparent.

Noticeable up to very strong dilution.

Uranium frit	:	Colorless glaze.
1 part	:	1–5 parts, yellow, with a greenish cast.
1 part	:	10 parts, very pale yellow.

The color disappears in thin layers almost completely on stronger dilution.

Copper frit	:	Colorless glaze.
1 part	:	1 part, bluish green.
1 part	:	3 parts, turquois-blue.
1 part	:	5 parts, light turquois-blue.
1 part	:	10–30 parts, sky-blue.

Glaze containing gold:

Colorless glaze with	0.1	per cent of gold, as gold-purple.	
Dark brownish red with	0.033	per cent,	rose color.
with	0.01	per cent,	light rose.

Glaze containing platinum:

White glaze with 1–0.1 per cent of platinum, ash-gray, the ones higher in platinum, opaque. Up to 0.01 of platinum, distinctly noticeable even in thin layers.

Glaze containing iridium:

With 1–0.1 per cent, blackish gray, opaque. Up to 0.01 per cent of iridium sesquioxide distinctly colored, even in thin layers.

If to the colorless glaze there is added 10 to 15 per cent of tin oxide, there are obtained white, opaque enamels, which fully resemble the lead-tin enamels used in the manufacture of ordinary faience.

In order to produce from the color frits and the colorless whiteware glaze, which form the foundation of the color decoration with transparent enamels, a series of colored glazes, systematic mixtures, each of two color frits, were prepared and these compounded with an equal quantity of colorless glaze.

For example, in order to observe the change which the glaze containing iron, undergoes through other additions, the following mixtures were made:

1 part iron frit	1 part manganese frit,	and 2 parts of colorless glaze.
	1 part nickel frit,	
	1 part cobalt frit,	
	1 part chromium frit,	
	1 part uranium frit,	
	1 part copper frit,	
	1 part glaze containing gold.	

Coincident with the proportion 1 : 1 : 2 colorless glaze, mixtures in the proportion 1 : 3 : 4 colorless glaze, and 1 : 9 : 10 colorless glaze, were made with all colored frits.

If these mixtures are applied to whiteware tiles, which are divided by molded ribs into a number of square, sunk panels, one is enabled to derive the desired proportions of mixtures for all possible color combinations from any two colored frits.

The mixtures possible in this manner were not all produced, but a selection was made which represents most of the color shades coming into use. If one, however, has thus made a series of color plates by systematic blending, it is not difficult to produce every desired shade by suitable mixing.

The colored glazes produced in the manner described should all have equal fusibility, if the law of Bischof-Richters, that fluxes can replace each other in equivalent proportions, without modifying the fusibility, is true, at least for the relatively low temperatures coming into consideration ; but this is by no means the case. On the contrary the different metallic oxides sometimes are more, sometimes less, energetic fluxes.

In order to determine the succession as to fluxing energy in which the metallic oxides, used as colors, rank in the glaze, equal volumes of the colored frits, mentioned above, were melted on to a clay surface inclined 45°. For this purpose the glaze frits were moistened with mucilage water until they became a workable mass, molded in a brass mold into tetrahedrons 20 mm. high and pasted with water over a horizontal line on a large clay tile. This was set into the muffle at an angle of about 45°. From the path, which the fused drop traced on flowing down the clay tile, a conclusion could be reached as to the degree of fluidity which the frit had attained at the melting-point of silver.

The strongest fluidity (path 20 cm. long) was shown by the colorless glaze (G V); then followed, nearly equal to it, the copper frit, 19 cm.; then in succession the manganese frit 10 cm., the iron frit 8 cm.; the chromium, uranium and cobalt frit, each run down the distance of 5 cm.; and finally the nickel frit, whose tetrahedron had not run, but had rounded to a thick drop. These differences in fusibility are quite considerable, but for practice they are less important, as most of the frits receive a large addition of colorless glaze.

For flat pottery, which can be burned in a horizontal position, the glazes produced from the colored frits and the colorless glaze proved very useful and applicable even in very thick layers (1 to 2 mm.), but not for hollow ware on which a strong running off and blending of the glazes takes place, especially when applied thickly. In order to render the glazes more viscous for the last-named purpose, an addition of feldspar or clay was given them, however, only in proportion to their content of colorless glaze. This addition amounted to 15 or 25 per cent of feldspar, 10 and 22.5 per cent of clay; the first values refer to glazes to be applied as a thin slip (up to about 0.5 mm.), the latter for glazes to be applied in drops, relief like. As a clay addition, Loethain white burning whiteware clay containing 61 per cent of clay substance and 39 per cent of quartz was used.

The following may serve as an example of the changes in the glaze composition:

Grass-green glaze:
  To be burnt in the horizontal position:
    1 part of uranium frit,
    3 parts of copper frit,
    4 parts of colorless glaze.
For vertical surfaces:
    1 part of uranium frit,
    3 parts mixture of $\left\{\begin{array}{l}0.85 \text{ copper frit,}\\ 0.15 \text{ feldspar,}\end{array}\right.$
    4 parts mixture of $\left\{\begin{array}{l}0.85 \text{ colorless glaze,}\\ 0.15 \text{ feldspar,}\end{array}\right.$
  or 1 part of uranium frit,
    3 parts mixture of $\left\{\begin{array}{l}0.9 \text{ copper frit,}\\ 0.1 \text{ clay,}\end{array}\right.$
    4 parts mixture of $\left\{\begin{array}{l}0.9 \text{ colorless glaze,}\\ 0.1 \text{ clay.}\end{array}\right.$

For reliefs:

1 part uranium frit,

3 parts mixture of $\left\{\begin{array}{l}\text{0.75 copper frit,}\\ \text{0.25 feldspar,}\end{array}\right.$

4 parts mixture of $\left\{\begin{array}{l}\text{0.75 colorless glaze,}\\ \text{0.25 feldspar,}\end{array}\right.$

or 1 part uranium frit,

3 parts mixture of $\left\{\begin{array}{l}\text{77.5 copper frit,}\\ \text{22.5 clay,}\end{array}\right.$

4 parts mixture of $\left\{\begin{array}{l}\text{77.5 colorless glaze,}\\ \text{22.5 clay.}\end{array}\right.$

There are thus obtained three series of colored glazes, which become bright and transparent at the same temperature, the melting-point of silver; but those compounded with feldspar only when they are applied on inclined surfaces; on horizontal surfaces they generally remain somewhat blistered or possess an eggshell-like appearance. In the calculation of the composition of colored glazes for hollow ware and reliefs, the red and gray glazes produced with gold, platinum and iridium must be treated like the colorless glaze.

III. ENGOBES AND COLORED OPAQUE CLAY PASTES (Schlicker)

Engobes are used for giving to a colored body a white coating, or to a white body a colored one, which forms a medium between body and glaze. These can be applied either to the raw, stiff, or biscuit-burned body. The engobes must possess a different composition, according to whether they are applied in one way or the other. If the engobe is applied to the raw clay, one employs, as a colored engobe on a white body, the same whiteware body compounded with coloring metallic oxides or underglaze colors in quantities from 1 to 10 per cent, since both layers must possess the same shrinkage in the biscuit burn. To produce a suitable white engobe on a colored body is unquestionably more difficult and can only be attained in each separate case by a series of empirical experiments by mixing white burning clay and quartz powder. But this difficulty may be lessened if the engobe is applied on the burnt whiteware or clay body. It will, however, be necessary in this case to fix the engobe in another burn previous to the glazing; for artistically valuable work this extra work of burning twice does not weigh against the decreased risk of the artist's work. If in turning, the vessel receives flaws or is crushed somewhat, this is very seldom recognized on green ware. The defect appears only after the biscuit burn, and with the appearance of cracks and the contortion of the shape, the application of the paste, the work of the artist, is lost. Thus it is always safer to decorate with engobe only such pieces which have emerged from the first burn free from defects. An injury to them in a second burn can only be brought about by gross carelessness. As in a second burn no more shrinkage of the base of the engobe or paste takes place, the composition of the paste must be adjusted only to such an extent that it may possess the properties which condition the most compact adhesion to the body possible.

The forces which rule the attachment of a raw clay body to a burned one are: 1, the cohesion of the molecules of the engobe to each other; 2, their adhesion to the body. Both act in different directions, the first toward bursting off, while the latter promotes the attachment to the ware. Both forces increase with the content of clay substance in the engobe, but in different degrees. In order to effect a sure attachment, the adhesion must always be the overbalancing force. In order to determine the most favorable proportion of clay base and non-plastic material for the production of engobes, the following experiment was made. Mixtures were made from clay (Ebernhahn clay) and finely ground sand in such proportions that they contained 10, 15, 20, etc., to 50 per cent of clay substance, the remainder being quartz powder. These were applied on the freely absorbing burned whiteware body, No. 1, as a thin paste so that a coating of 0.2 to 0.5 mm. thickness was formed over the surface.

The trial pieces were then burned up to the temperature of the expulsion of the chemically combined water in the clay substance (melting-point of silver). All of the engobes adhered to the body on drying, but none of the mixtures named adhered to the body sufficiently after burning to be used as an engobe. The least peeling was shown by the mixtures which contained 25 to

35 per cent of clay substance, while the more plastic as well as the more non-plastic ones proved to possess less adhesion. According to this a content of from 25 to 35 per cent of clay base in the paste must be looked upon as being the relatively most favorable proportion.

In order to increase the adhesion of the paste in burning, an addition of glaze was given it. This by its melting not only fixed the paste to the body, but also imparted to the latter a certain elasticity, so that in the contraction necessarily following the burning, no fracture of the paste could take place, but a stretching of it was rendered possible. In order to determine the quantities of the glaze to be added at the standard temperature (melting-point of silver) mixtures were produced of 10, 15, 20, etc., to 50 per cent of glaze G V with whiteware body No. 1 (35 per cent of clay substance, 65 per cent quartz). All the trial pieces were satisfactory as to adhesion; with 10 per cent of glaze, the engobe was yet very soft; with 15 per cent, it was but little absorbent; with 30 to 50 per cent, dense and glossy.

The mixture with 15 per cent of glaze was hence the best and was exclusively used for all of the other experiments with engobe and paste decoration.

The composition of this mixture, serving as a white engobe and basis for the production of colored pastes, expressed in percentage, is as follows:

	Per cent.
Glaze G V	15.00
Clay substance	29.76
Quartz (and feldspar)	55.25
or Glaze G V	15.00
Whiteware body No. 3	85.00

This engobe proved stable at silver-melting heat, on every porous body, not shrinking any more at this temperature, and it may be a white or colored whiteware body, a marl or grog body. Hence it may as well serve for the hiding of the coarse and more or less discolored grog body as after the addition of colors for the application of paste-painting on a whiteware body.

In order to produce colored bodies by means of the white paste to be applied in the pasty condition, it was mixed with underglaze colors, as sold on the market. In most cases a sufficiently strong color is obtained by an addition of 10 parts of color to 100 parts of dry engobe. On making such mixtures, burning them on to a body and covering them with a glaze, there is offered to the painter a reliable basis for modifying the colors for his purposes by diluting with white clay paste or by adding colors on the pallette.

The application of paste has no influence upon the stability of the glaze; whether or not it proves stable on the body, whether or not it crazes or shivers, depends solely upon the constitution of the body and the glaze. The behavior of the body and the glaze is always the same without regard to whether the latter is separated from the body by a thin layer of engobe, or whether it is in direct contact with the body, as long as the intermediate layer is not too thick,—several millimeters in thickness.

IV. Translucent Colored Clay Pastes

If the content of glaze in the clay paste is increased much over 15 per cent, there are obtained bodies which receive the characteristics of frit porcelain at the melting-point of silver; at this temperature, the melting-point of the barium glaze, accepted, they become dense, receive a dull glaze-like appearance and a certain transparency.

White clay paste, composed of 35 per cent of glaze G V and 65 per cent of whiteware body, gives a paste which could be employed on a colored clay body in the place of a tin enamel, and permits the production of effects on whiteware similar to those obtained by the *pâte sur pâte* decoration. The paste covers perfectly in thick layers; when thinner, however, it allows the coloration of the body under it to appear.

On compounding a whiteware body instead of with a colorless glaze with any of the colored glazes, whose preparation has been described above, in the above-named proportion, a color scale of translucent pastes is obtained, which is well adapted to relief-like decorations, on colored as well as white bodies. If the content of colored glaze in the clay paste is 35 per cent, it does not become sufficiently brilliant to be used on the body without a glaze. But if the content of colored glaze is increased to 50 and 60 per cent, these pastes become at the melting-point of silver sufficiently brilliant to be used for many other decorative purposes without a coating of colorless glaze applied over them.

V. DECORATION

The decorative techniques which can be carried out with the means so far described, and of which trial pieces have been made at the experimental laboratory, are as follows:

A. *On the green unburnt body.*
  - *a.* Painting with colored or white body paste after the biscuit burn to be decorated with underglaze colors or colored glazes.
  - *b.* Excising of engobe on the air-dry body (technique of the Doulton stoneware).

B. *On the burnt body.*
  - *c.* Painting with opaque white or colored pastes on a white or colored body (paste painting).
  - *d.* Painting with translucent colored pastes (corresponding to the *pâte sur pâte* painting on porcelain and the faience of Fünfkirchen).
  - *e.* Painting with white translucent paste on a colored body (corresponding to the *pâte sur pâte* work of Sevres).
  - *f.* Painting with colored glazes and outlining by means of relief-like clay pastes (decoration of the faience of Th. Deck).
  - *g.* Work in relief-like glazes between contours in oily color (faiences of Gien and Longwy).
  - *h.* Excising in engobes (Sgrafitto).

A. Decoration on the Green Body

a. Painting with colored or white body paste after the biscuit burn to be decorated with underglaze colors or colored glazes.

The ware must be decorated as soon as it is stiff enough after molding so that it may be handled; if it becomes too dry the paste applied, as a rule, peels off in the biscuit burn. For painting there is used a paste of whiteware body, without an addition of glaze or adhesive material but colored according to the requirements by an addition of underglaze color.

The application is accomplished by means of a painting tube or a brush. After drying, the work goes to the biscuit kiln to be burned to ordinary hardness, is then covered with a colorless or colored glaze by dipping, and finally is taken to the glost burn. The risk of the work being injured in the biscuit burn is rather great, as the soft ware is easily crushed or receives hidden cracks which appear only after the burn. The relief-like decoration breaks off easily, if the body is dried too rapidly at first.

b. Excising of engobe on the air-dry body (decoration of the Doulton stoneware).

The designs to be applied are scratched in with a needle about 0.5 mm. deep. In order to let the scratches appear colored, underglaze color, ground in water, is filled into the scratches by means of a long-haired brush or the pieces are covered with a colored glaze after the biscuit burn. In the first case after complete drying of the color the piece is rubbed off with a leather or flannel cloth in order to remove the color which has gotten on to the surface. The color remaining in the scratches burns firmly to the body in the biscuit burn. In the second case the colored glazes produce a decorative effect owing to their greater thickness along the scratched lines. Should many pieces be produced according to the same design, the excising is done on a model made of plaster; in the molds the design will then appear raised and sunk on the ware made from them.

B. Decoration on the Burnt Body

c. Painting with opaque white or colored clay pastes on a white or colored body (paste-painting).

The body must be quite absorbent and is to be rubbed well before painting with sand or emery paper in order to remove all loose dusty particles from the surface.

A colored background is obtained by coloring the body either by means of an addition of coloring metallic oxides to the whiteware body, or by dipping the burned body into solutions of metallic nitrate or acetates, or finally by brushing with or dipping into an engobe, compounded of glaze and color. In the latter case it is possible to paint on the colored engobe immediately without previous burning. On saturating the body with a metallic salt solution, the former must be burnt at a low temperature.

For painting there serves a paste consisting of 85 parts of whiteware body, containing 30 to 35 per cent of clay substance, and 15 parts of whiteware glaze. To this are added underglaze colors according to need. It is advisable to keep mixtures of 100 parts of paste and 10 parts of underglaze color in stock, and to burn them on to a piece of body to be used as reference for the painter. The colored pastes can be made deeper in shade on the palette as needed, or may be diluted by the addition of color or white paste. The colors can for this purpose be advantageously ground in glycerine and kept in stock in tubes.

The application of the paste requires some experience especially if applied in a layer several millimeters thick. It is especially important to consider its consistency which must be governed by the absorbing power of the body. The liquid must be of such a character that the engobe loses its gloss in two to three seconds. If it is too stiff, so that it is immediately dried by absorption of the water into the body, or if the brush even sticks to the body, or on the other hand so thin that it stands some time on the body without becoming solid by the loss of water, there is danger of peeling on drying or in burning. In working with very thick pastes applied on a strongly absorbent body, it is best to fill the pores first with a coating of a very thin engobe. Upon this layer there is then applied the real relief-like coating by means of a thick engobe. The surface of the coating of paste may be decorated by painting, but the absorption of the body must be carefully considered ; the lower coating of paste must not be softened again. If, owing to the absorption of water, the body has lost its absorbing power it must first be dried so that the softening of the painting may be prevented. With very thick pastes it is advisable to stiffen them by an addition of sirup or sugar water. The surface of the paste may be decorated with colors by following the directions given. With some experience it is possible to apply paste coatings 5 mm. and more in thickness without cracking. After drying the paste painting slowly, it is to be burned at the temperature at which the glaze mixed with it burns to a smooth glass. If cracks appear in the paste, they may be filled before glazing with a thin slip without showing after glazing. A previous burning of the paste is unnecessary provided the retouching of the painting is restricted to the filling up of small cracks.

d. Painting with translucent, colored pastes (decoration of the Fünfkirchen faience).

The body is to be treated as before and the pastes are also applied as shown above. The clay paste contains sufficient glaze, so that in the glost burn the mixtures assume a porcelain-like appearance, that is, appear translucent at the edges and in thin layers, and become somewhat glossy. According as the body is to show more or less through the coating applied above it, mixtures of more or less glaze can be used, the proportions varying between 30 and 50 parts to 70 and 50 parts of whiteware body.

The pastes are colored, not by the addition of opaque underglaze colors, which would render them opaque, but by dissolved metallic oxides. This is done in the preparation of the pastes by adding, to the whiteware body, colored in place of colorless glazes. For every colored glaze there is a translucent paste corresponding to it in shade. The painting of the surface of the paste with underglaze colors is permissible for the purpose of shading, observing the precautions given under the head of opaque pastes. After the drying of the paste the piece must be burned at a somewhat lower temperature than is necessary for the smooth burning of the glazes used in order that the pastes may retain a slight absorbing power which is necessary when the vessel is glazed with a colorless or colored glaze.

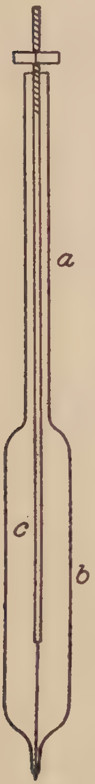
e. Painting with white, translucent paste on a colored body (corresponding to the *pâte sur pâte* work of Sevres).

The whiteware body may be colored in such a way that coloring metallic oxides are added either directly to the body, or naturally colored clays may be used, or finally the whiteware may be saturated with solutions of nitrates or acetates of the metallic salts and the acids expelled by ignition.

The paste used in painting in this work is always white, and consists of whiteware body and glaze. The color effects are produced by covering the body with paste and varying the thickness of the latter. The mixture most suitable for this purpose consists of 65 parts of whiteware body containing 30 to 35 per cent of clay substance and 35 parts of colorless glaze. Places to be covered completely in white require of this mixture a coating about 2 mm. thick. The translucency which the paste assumes in the glost burn corresponds about to good, translucent, white porcelain. In using this material, not only painting, but also modeling is involved. This modeling is first done roughly by application with the brush followed by the working out of the designs by means of the modeling tool and needle. The precautions given under the head of opaque pastes are to be observed. After the drying of the paste the piece is burned and then dipped in a colorless glaze.

f. Painting with colored glazes and outlining by means of relief-like pastes (decoration of the faience of Th. Deck).

The color is here produced by transparent glazes which are applied on the body, mosaic-like, beside each other. In order that they may not flow into each other it is necessary to divide the separate surfaces by means of a solid non-fusing partition. The division of the separate colored glazes can be carried out either (as is done in the manufacture of floor tiles by Minton at Stoke) by molding the contours as raised ribs in the body itself, or by means of the brush. The former method is carried out in such a way that the contours of the drawing are scratched into the plaster mold by means of a pencil. These, after molding, appear raised. According to the second method the contours are painted on as small ribs or are applied by means of a special pen. The most suitable material for the production of the relief-like contours is a clay paste of 30 per cent glaze and 70 per cent whiteware body containing 30 to 35 per cent of clay substance. For coloring the contours underglaze colors are added to this clay paste. Pastes higher in glaze flow as they are attacked by the glazes; those lower in glaze shrink less, project too much above the glaze and are apt to be dull in appearance. The application of the pastes as thin ribs, separating the glaze divisions by means of a pointed brush, is very tedious and slow, since it must be applied repeatedly in order to reach the required height, 1 to 1.5 mm. The raised contours of this technique are applied in more pronounced lines and in a single application by means of the following little instrument: This consists of a glass tube *a*, 4 to 5 mm. wide, to which a wider tube, *b*, is fused below, which serves as an engobe reservoir. The lower wider tube is provided with a fine point. A heavy metal wire, *c*, goes through the length of the instrument and is held by a loose nut on top of the glass tube. A sewing needle is soldered to the lower end of the wire which extends through the fine point of the glass tube a distance of from 2 to 3 mm., and fits the opening of the latter quite loosely.



The paste is ground with one part of glycerin and two parts of water to a cream-like consistency, poured through a sieve and taken up into the apparatus through the point by sucking at the upper end of the glass tube.

A small drop of paste always hangs on the point of the needle, and is constantly being replaced on writing with it, as owing to the vibrations of the needle due to the scratching on the body, some paste continually escapes along the needle through the fine glass point.

If the design is such that the entire surface of the ware must be covered with glaze by means of the brush, this can be done without hardening the outlines by biscuit-burning the piece of work. However, if a ground-glaze is to be applied which, for the sake of greater uniformity, is to be applied by dipping, the real design must be protected from contact with the glaze.

This can be done in two ways:

1. The design proper may first be covered with the glazes, and the glazed portions are then, without fritting the glazes, coated with a mixture of wax and oil of turpentine and finally the piece is dipped in the glaze for the ground. This method gives good results only when the body absorbs well and the glaze can be applied rather thinly.

2. The ground can be applied first. For this purpose the surface divisions of the design proper are protected by means of a coating with a thin paste of 1 part of China clay, 5 parts of wheat flour and 0.1 volume of rape-seed oil.

After the drying of the coating the piece is drawn through the ground-glaze; the excess of the latter is trimmed off, and the piece is heated to dark red heat, in order to destroy the flour paste and to burn the glaze so solid that it cannot be rubbed off on subsequent handling. After the heating the ground-glaze drops off from all such portions of the piece which had been covered with flour paste. This method occasions a greater loss of glaze than the one first described; however, it offers a greater assurance of uniformity of the ground-glaze and permits of an even application of the ground, even on harder burned bodies. After the places, which had been protected by the application of flour paste, are freed from glaze and ashes from the paste by brushing, the design is now completed by inlaying the colored glazes with a brush. For pieces which can be burnt in a horizontal position in the muffle and for those parts, on which a flowing off of the glaze is not to be feared, the colored glazes corresponding to the glaze G V of the general formula $RO + 3SiO_2$ (4 : 1) were applied; and for ware burnt in the vertical position a mixture of this with 10 per cent of Loethain clay corresponding to the formula $RO, 0.1Al_2O_3, 3.3SiO_2$ (4.5 : 1) was used.

The glaze on surfaces burnt in the horizontal position may be applied in a thickness of 2 mm., in the vertical up to 1 mm.

The colors produced by this glaze technique, may be modified in two ways. The colored glazes may be deepened in shade by the use of underglaze colors or by the use of opaque colored pastes. Light shades may be produced by the use of transparent, white paste under the glaze by which the thickness of the glaze is decreased. This work must be done before the application of the flour paste, and these modifications are fixed in the burning off of the latter.

g. Painting with relief glazes.

The decoration of whiteware by transparent or relief glazes made opaque by tin oxide is carried out, by producing, by printing or painting, dark-colored borders; on the surface divisions thus formed, colored glazes are applied in heavy drops.

To keep the separate glaze drops from flowing into each other, it is necessary to apply the outline colors ground together with a fatty substance. In printing, this requirement is always fulfilled by the printing varnish. For painted outlines there may be used any fat oil, linseed oil, rape-seed oil, or oil of lavender. The best protection of the color lines against the glaze, which is applied as a watery slip, and consequently the quickest and safest procedure is followed by using a solution of 1 part of wax and 10 parts of oil of turpentine in the grinding of the outline colors. In order that the glazes, standing up pearl-like on the body, should not attack the latter too strongly, thus causing the glaze drops to flow together in the fire, it is necessary to make the glazes used for this purpose as difficultly fusible as possible.

The glazes used in the decorations discussed so far do not answer this requirement, especially not when the surface to be decorated, as is always the case in hollow ware, must be burnt in the vertical position. It was thus necessary to produce a separate series of glaze for this purpose.

The glazes were produced by replacing the most fusible ones (the colorless glazes and the copper glaze frit) by mixtures of 77.5 parts of glaze corresponding to glaze G V, and 22.5 parts Loethain whiteware clay. The composition thus approached

$$RO, 0.25Al_2O_3, 3.5SiO_2\ (4.8 : 1).$$

The remaining colored frits entered into the glaze mixtures unaltered, being sufficiently viscous. Since all the glazes consist of at least half of colorless glaze, all glaze mixtures used as relief glazes contain between 11.25 and 22.5 per cent of clay.

h. Excising in engobes (Sgrafitto).

For carrying out this method of decoration, ware of dark red color is used, which is covered with a white coating, or white pottery with a dark coating. The pastes described under the topic of painting with pastes consisting of 85 per cent of whiteware body containing from 30 to 35 per cent of clay substance, and 15 per cent of glaze with a corresponding addition of color are used in this technique. These are ground finely and the biscuit-burnt pieces to be decorated dipped into the slip, so that they received a thin coating. The excision in the coating is accomplished by cutting through with the needle, so that the burnt body is shown and the design thus appears in colored lines on a white ground or in white lines on a colored ground. In order that a certain brittleness, possessed by the clayey coating in the dry condition, does not impair the sharpness of the lines by the breaking off of flakes the excision must be accomplished either before the body and its coating is completely dried, or as this, especially on larger pieces, is not always possible, the coating must be brushed over with glycerin, which keeps it quite pliable. After finishing the excision the decorated ware must be biscuit-burnt at silver-melting heat, in order to destroy the glycerin and to fasten the engobe. Then follows the application with a colorless or colored glaze in the ordinary manner.

Whiteware Glazes with the Use of Barium Sulphate (Barite)

ALBERT BLEININGER, B.SC., TRANSLATOR

The experiments conducted by the chemical-technical experiment station for the decoration of whiteware with glazes containing barium were hitherto based first on the use of pure barium carbonate for the production of the glazes. But for the manufacture on a commercial scale this would be too expensive a material, and the glazes would be considerably more expensive than those produced with lead oxide or white lead. This reason alone would incite opposition to the barium glazes. For this reason a cheaper source of barium must be found.

It would appear to be the simplest way to make use of witherite, a natural barium carbonate as a source of barium, which is brought on the market at a very low price. However, there must be considered, that very often witherite is intergrown with other minerals and by no means offers that assurance of its purity which, for instance, lead oxide or white lead can claim.

Again, witherite has not yet been found in Germany in such quantities that the mineral could be utilized industrially, and the whiteware industry would have to depend on the import from foreign countries.

These considerations led to the attempt to use another barium mineral as the source of the barium, which is obtained in Germany in a condition of great purity and in large quantities, and also is to be had at such low prices that it represents, without doubt, a cheaper source of flux than the usual lead preparations, so that with its assistance the cost of the glaze could be lowered. This mineral is barite (heavy spar), sulphate of barium.

Barite has already been used as a flux in the clay industry. It has occasionally been applied in place of feldspar as a flux for bodies, and also as an addition to glaze, however, only in small quantities and together with predominating quantities of lead oxide.

This use of barium, however, has taken place only in isolated cases and then only by way of experiment, and has not proved a success, at least not in glazes, as these are apt to become blistered and opaque through such an addition. True barium glazes, that is, those in which lead oxide has been replaced by barium, have not been used so far in practical work at large, and heavy spar was never thought of as a glaze material.

In order to find the reasons why the introduction of heavy spar as a glaze material has so far been attended only by negative results, it was first necessary to determine how barium sulphate behaves in glazes in its relation to the other ingredients used during fusion.

It is known from the manufacture of glass that the alkaline sulphates are difficultly and imperfectly decomposed by silicic acid and that a great part escapes decomposition, floats on top of the glass as gall and must be removed before working the glass. The decomposition takes place readily only when carbon is added to the glass which decomposes the sulphuric acid into sulphurous acid and carbonic acid.

Now the task remained to determine whether the barium sulphate is equally difficult to decompose, whether perhaps it is soluble in the glass on removing the alkaline sulphates in the shape of glass gall, or finally whether it is simply decomposed and the sulphuric acid driven off.

The following glaze batches were melted in crucibles at about the melting-point of gold.

Barium glaze *a*.

Barium sulphate	116.5 = 1 equivalent BaO,SO_3
Sodium carbonate	106.0 = 2 equivalents Na_2O,CO_2
Hydrous boric acid	62.0 = 1 equivalent B_2O_3
Sand	150.0 = 5 equivalents SiO_2.

Under the assumption that the sulphuric acid is simply driven off, a glass should be produced of the composition

$$a.\quad BaO,\ 2Na_2O,\ 5SiO_2,\ 1B_2O_3,$$
$$RO,\ 2SiO_2\ (1:5);$$

hence, a bisilicate, or if the sulphuric acid is not driven off, but as sodium sulphate passes into the gall

$$b.\quad BaO,\ Na_2O,\ 5SiO_2,\ 1B_2O_3 + Na_2O,\ SO_3,$$
$$RO,\ 3SiO_2\ (1:5),$$

hence a trisilicate.

Barium glaze *b*.

Barium sulphate	116.5 = 1 equivalent $BaO,\ SO_3$
Sodium carbonate	106.0 = 2 equivalents $Na_2O,\ CO_2$
Hydrous boric acid	62.0 = 1 equivalent B_2O_3
Sand	90.0 = 3 equivalents SiO_2.

Under the previously made suppositions the process is represented by the following formulas:

a. $BaO, 2Na_2O, 3SiO_2, 1B_2O_3$ = a $1\frac{1}{3}$ silicate,
$RO, 1.33SiO_2$ (1 : 3).
b. $BaO, Na_2O, 3SiO_2, 1B_2O_3 + Na_2O, SO_3$ = a bisilicate,
$RO, 2SiO_2$ (1 : 3).

The two glass compositions mentioned above were melted in equal quantities in two crucibles in the same muffle, at gold-melting heat, therefore under exactly similar conditions. After fusion and the breaking of the crucible two layers were shown; the lower layer formed a clear, pure, and strongly refracting glass, the upper one a salt-like substance, crystalline in character, which dissolved in water, leaving behind a slight quantity of sand and barium sulphate, and proved to be sodium sulphate. Hence the supposition *b* took place; that is, the barium had entered the glass as a silicate, while at the same time a corresponding part of the soda was removed in the form of sodium sulphate.

The analysis of the clear, lower layer gave the following result:

	Barium glaze *a.*		Barium glaze *b.*	
	Found.	Calculated under assumption *b.*	Found.	Calculated under assumption *b.*
Barium oxide	19.99	26.15	30.81	32.87
Soda	——	10.59	——	13.33
Boric acid	——	11.97	——	15.09
Silica	50.22	51.29	35.01	38.71
Sulphuric acid	1.69	——	4.15	——
This amount of sulphuric acid corresponds to	4.92	——	12.09	——
	($BaSO_4$)	100.00	($BaSO_4$)	100.00

From this follows: that first a double decomposition between barium sulphate and soda actually takes place, the barium passing into the glass and the soda to the gall; second, that this decomposition does not take place perfectly, and that a part of the barium sulphate escapes decomposition and is taken up mechanically by the gall; third, that part of the sulphates remain dissolved in the glass and that the content of sulphuric acid is the greater, the less acid the glass is.

According to this result an addition of barium sulphate not only seems entirely useless, because thus no flux is introduced by it, since a quantity of alkali corresponding to the amount of the barium taken up is removed, but it acts injuriously inasmuch as it introduces into the glaze sulphuric acid which cannot be removed by washing.

According to the results of the preceding analysis it might be supposed, that on increasing the silicic acid content of the glaze a part of the sulphuric acid taken up by the glass would be vaporized.

An experiment confirmed this assumption. While both glazes fused into clear glass beads on the platinum wire before the blowpipe, they gave, after addition of slight quantities of silica or clay, foaming, opaque, slag-like masses. The same was the case when they were burned on a whiteware body, either alone or mixed with slight quantities of clay. They did not produce bright, but dim, film-like and blistered glazes. Since an absorption of silicic acid by the glaze from the whiteware body always takes place, such glazes containing sulphuric acid could never be used to any advantage. An addition of only 2 per cent of barium sulphate or gypsum to glazes, previously found satisfactory, and composed of materials free from sulphuric acid, produced the same phenomenon; even the quality of the water, with which the glazes are prepared, may give rise to an injurious influence if it is high in sulphates.

On account of the injurious effects which a balance of undecomposed sulphates exerts, a different procedure had to be found. The same method was followed which is made use of in the manufacture of glass for the production of mirror glass direct from sodium sulphate, by melting the glass composition together with a certain addition of powdered charcoal, in order to reduce the sulphuric acid to sulphurous acid and thus to volatilize it more readily. This method led to a favorable result.

Corresponding to the glaze *a*,

$$BaO, Na_2O, 5SiO_2, 1B_2O_3$$
$$(RO, 3SiO_2)\ 1 : 5,$$

the following glaze mixture was prepared:

Barium sulphate	116.5
Sodium carbonate	26.5
Crystallized borax	95.5
Sand	150.0
Charcoal	12.0

The glass obtained in this way showed the following composition by analysis:

	Found. Per cent.	According to theory. Per cent.
Barium oxide	26.57	26.15
Soda	——	10.59
Boracic acid	——	11.98
Silicic acid	50.60	51.28
Sulphuric acid	0.30	——

The agreement is almost perfect.

The content of sulphuric acid was reduced to a minimum, which practically did not prove injurious. The same result was obtained in melting a more basic glaze of the composition

$$BaO, Na_2O, 4SiO_2, 1B_2O_3$$
$$RO, 2.5SiO_2\ (1 : 4),$$

from the following raw materials:

Barium sulphate	116.5
Sodium carbonate	26.5
Crystallized borax	95.5
Sand	120.0
Charcoal	12.0

The analysis of the frit obtained from it showed:

	Found. Per cent.	According to theory. Per cent.
Barium oxide	28.33	29.15
Soda	——	11.81
Boracic acid	——	13.33
Silica	45.12	45.71
Sulphuric acid	1.16	——

There remained yet to determine whether equally favorable results are obtained, when in place of the pure barium sulphate, barite, as found in nature, is used. A somewhat gray-colored in kind of heavy spar, obtained from the trade, of unknown origin was found to have the following composition:

Iron oxide	trace
Alumina	trace
Barium oxide	61.81
Calcium oxide	4.12
Fluorine	3.42
Sulphuric acid	32.14

Thus the heavy spar represented a mixture of 73.64 per cent of barite and 6.36 per cent of fluor spar.

As a preliminary experiment had proved that on melting the glaze the fluorine was entirely volatilized, the lime, replacing barium, was calculated as a flux; in the computation of the composition the fact was also considered that in fusion a quantity of silicic acid, corresponding to the content of fluorine, is volatilized as silicon fluoride.

Thus for a trisilicate of the composition

$$BaO, Na_2O, 5SiO_2, 1B_2O_3$$
$$RO, 3SiO_2\ (1 : 5),$$

the following glaze batch is obtained :

Barite	124.0
Calcined soda	31.8
Crystallized borax	114.5
Sand	179.7
Charcoal	15.0

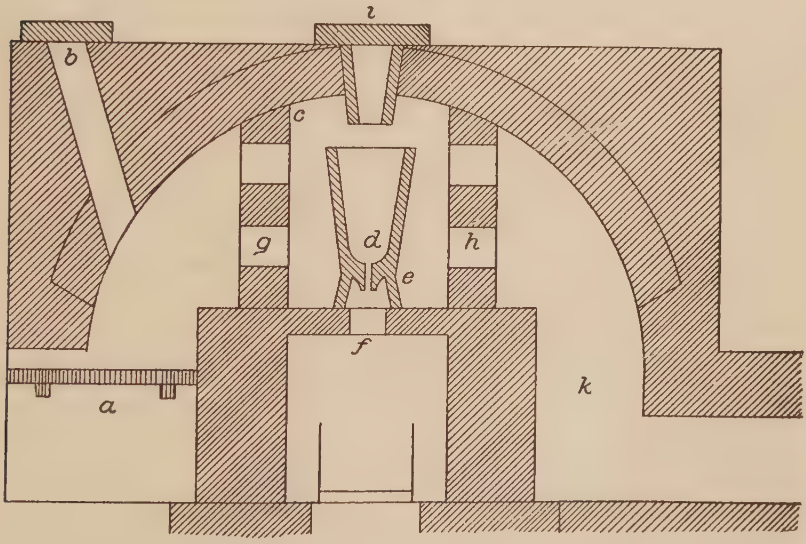
A heavy spar from Niedersachswerfen which contained 7 per cent of silica, but no calcium fluoride, required for the production of a glaze, as given above, the following batch:

Barite	125.3
Calcined soda	26.5
Crystallized borax	95.5
Sand	141.2
Charcoal	15.0

Both glazes, so produced, formed perfectly clear glasses on being melted in the manner described later on. On being applied after grinding as a glaze on the usual whiteware body, they produced very bright, strongly refracting glaze coatings at silver-melting heat. The glaze, in consequence of its higher barium content (it contains half of the equivalent amount of flux as barium, while the glaze formerly used contained only one-fourth as barium), is more fusible than the trisilicate glaze G V employed so far, and subsequently served exclusively as the base for the whiteware decoration. The glaze produced from the Niedersachswerfen heavy spar is being used exclusively in the chemical-technical laboratory for the manufacture of whiteware, for years, with unvarying success.

The fritting of the glaze cannot be done in saggars in the biscuit burn, as is ordinarily done, because the charcoal would burn out at a lower temperature, without producing the desired result, but a specially constructed frit kiln is to be used, which prevents the burning out of the coal.

In the chemical-technical laboratory at the Royal Porcelain Factory, the frit-kiln illustrated below is in use for melting the frit.



a is the grate which is fired with coal through an opening, *b*, covered with a clay tile. The furnace space proper *c*, is formed by an arch, beneath the center of which two Hessian crucibles, *d*, are placed behind each other. The Hessian crucibles have a projection at the bottom with a hole of 3 to 4 mm. for the flowing out of the liquid glaze into a vessel filled with water placed beneath the furnace. The crucibles stand on a ring-like base of glass pot clay, *e*, above an opening in the bottom of the furnace *f*. For the distribution of the fire and to prevent cooling off, two perforated screen walls are built up in the furnace space in front and behind the pots. For the charging of the frit there serve the openings *i*, which may be covered with tiles; *k* is the exit of the fire-gases. The frit-kiln is operated as follows:

The furnace is first brought to a bright heat. Then through the openings *i* the glaze batch is charged into the crucibles below. Decomposition takes place immediately and without foaming; the liquid frit collects at the bottom of the pots and flows off continuously in a rather strong stream through the holes in the bottom into vessels filled with water placed beneath the furnace.

At the rate at which the pots discharge their content, fresh frit is fed from the top. It is thus possible to melt in a furnace with two small Hessian crucibles, 35 cm. high, 100 kg. of frit in twelve hours; should the output be increased either more crucibles are to be put in the furnace, or larger ones must be used.

If the crucibles are coated with a mixture of chopped straw and fire-clay to a thickness of 1 to 2 cm. they last very long; some of them have been used five to six times.

Since the barium oxide introduced into the glaze from heavy spar, not only represents the cheapest available flux, but also imparts to the glazes a greater brilliancy as well as a stronger refraction of light, and to the underglaze decoration more vivid colors, beside rendering the glazes more fusible, it was endeavored, although the content of barium has been raised by the adoption of the glaze (barium glaze *a*) in place of the one previously used, G V, from 13.8 to 26.2, to increase the content of barium still more at the expense of the sodium content.

It was also tried to decrease, simultaneously, the content of boracic acid at the expense of the silica.

The following glaze compositions were thus fused:

Compositions with a rising barium content:

a. $3BaO, Na_2O, 12.5SiO_2, 2.5B_2O_3$
$RO, 3SiO_2$ (1 : 5).

b. $2BaO, Na_2O, 7.5SiO_2, 1.5B_2O_3$
$RO, 3SiO_2$ (1 : 5).

Compositions with a decreasing boracic acid content:

c. $BaO, Na_2O, 5.33SiO_2, 0.66B_2O_3$
$RO, 3SiO_2$ (1 : 8).

d. $BaO, Na_2O, 5.5SiO_2, 0.5B_2O_3$
$RO, 3SiO_2$ (1 : 11).

Both changes of the barium glaze *a* did not prove feasible. With a still higher barium content of the glazes and a simultaneous decrease of the sodium content the glazes showed the property of high lime glasses, low in alkali, to become dim on slow cooling. On decreasing the boracic acid content and with a corresponding addition of silicic acid the glazes assume a noticeable tendency to devitrification. Hence, if it is intended to use such glazes as a basis for the production of colored glazes, which shall be as low as possible in alumina, it will not be wise to exceed a barium content equal to half of the fluxes (in equivalent weights) and it is best to select a content of boracic acid, which does not go below one-fifth of the equivalent of silicic acid.

The glazes described above cannot well be used in place of an ordinary whiteware glaze since they, as explained above, require a body very high in quartz, which, however, offers difficulties in the manufacture on a commercial scale.

They are used only where the consideration of a rich color scale makes the employment of glazes free from alumina desirable. However for the bodies, high in alumina, of the ordinary whiteware industry, which manufactures utility ware, the barium glaze described might well serve as a frit.

The more aluminous bodies of the whiteware industry require a glaze which possesses not only a certain content of alumina in order to avoid devitrification on long-continued firing, but which also must have a rather high silicic acid content so as to avoid crazing. This content of silica must be the larger and the glaze the more difficultly fusible, the higher the body is in alumina. The glost kiln temperature of the ordinary whiteware glazes may begin at a temperature, which fuses an alloy of 50 parts of silver and 50 parts of gold, approximately 1050° C.; that of the most difficultly fusible ones may be at about the melting-point of 85 per cent of gold, 15 per cent of platinum, approximately 1300° C. Glazes which have a melting-point above or below these points are scarcely ever used.

Glazes of this kind are very easily obtained from the barium frit, if the latter is mixed with clay and sand, thus making the glass aluminous as well as higher in silica.

The following table represents a few of these mixtures:

	Frit: $BaO, Na_2O, 5 SiO_2, B_2O_3$ $RO, 3 SiO_2$ (5 : 1).	Zettlitz clay.	Sand.	Melting-point.
(BaO, Na_2O), $0.1 Al_2O_3$, $3.25 SiO_2$, (5.5 : 1)	292.5	25.9	3.0	about melt'g-pt. of silver.
(BaO, Na_2O), $0.1 Al_2O_3$, $3.50 SiO_2$, (6.0 : 1)	292.5	25.9	18.0	between melting-pts. of silver and gold.
(BaO, Na_2O), $0.1 Al_2O_3$, $3.75 SiO_2$, (6.5 : 1)	292.5	25.9	33.0	
(BaO, Na_2O), $0.1 Al_2O_3$, $4.00 SiO_2$, (7.0 : 1)	292.5	25.9	48.0	below gold-melting heat.
(BaO, Na_2O), $0.2 Al_2O_3$, $3.50 SiO_2$, (6.0 : 1)	292.5	51.8	6.0	about 50 silver, 50 gold.
(BaO, Na_2O), $0.2 Al_2O_3$, $4.00 SiO_2$, (7.0 : 1)	292.5	51.8	36.0	about gold-melting heat.
(BaO, Na_2O), $0.2 Al_2O_3$, $4.50 SiO_2$, (8.0 : 1)	292.5	51.8	66.0	above gold-melting heat.
(BaO, Na_2O), $0.2 Al_2O_3$, $5.00 SiO_2$, (9.0 : 1)	292.5	51.8	96.0	about 90 gold, 10 platinum.
(BaO, Na_2O), $0.3 Al_2O_3$, $4.00 SiO_2$, (7.0 : 1)	292.5	77.7	24.0	above gold-melting heat.
(BaO, Na_2O), $0.3 Al_2O_3$, $4.50 SiO_2$, (8.0 : 1)	292.5	77.7	54.0	about 95 gold, 5 platinum.
(BaO, Na_2O), $0.3 Al_2O_3$, $5.00 SiO_2$, (9.0 : 1)	292.5	77.7	84.0	about 90 gold, 10 platinum.
(BaO, Na_2O), $0.3 Al_2O_3$, $5.50 SiO_2$, (10 : 1)	292.5	77.7	114.0	about 85 gold, 15 platinum.

For the temperatures ordinarily applied one of these glazes will answer; should this not be the case and the body require a glaze very rich in alumina as well as very fusible, the frit could be made more fusible by increasing the boracic acid content.

For example for a frit of the formula

$$BaO, Na_2O, 4.5SiO_2, 1.5B_2O_3 \ (3 : 1),$$

the batch will be as follows:

Barite	125.3
Calcined soda	13.25
Crystallized borax	143.20
Sand	126.20
Charcoal	15.00

or for an extremely fusible frit of the composition

$$BaO, Na_2O, 4 \ SiO_2, 2 \ B_2O_3 \ (2 : 1),$$

Barite	125.3
Crystallized borax	191.0
Sand	111.2
Charcoal	15.00

For the glaze mixtures containing clay and sand the proportions previously given remain the same, with the exception only, that the proportional amount of the first frit is to be taken as 295.0, for the second as 297.5. Of course the figures given above are good only for the heavy spar used; for heavy spars from other sources and different composition the proportions must be changed accordingly.

The Influence of Sulphuric Acid on Glazes and Bodies

ALBERT BLEININGER, B.SC., TRANSLATOR

The injurious effects of sulphuric acid upon glazes, enamels and bodies have hitherto been totally disregarded. One is accustomed to think of glazes as composed of lead oxide, alkalies, lime, alumina, boracic acid and silica. But few consider that sulphuric acid is an ever-present ingredient of the glazes. The bodies are composed of kaolin, ball-clay, feldspar, sand, lime, bone-ash, etc., and the sulphuric acid present is not found worthy of consideration. And yet its presence is of importance in both cases and must be considered small as the quantity in itself might be.

Of all the salts which enter into glazes by intention or accidentally, the sulphates are most difficult to decompose. The salts formed with acids of organic origin are very easily destroyed: carbonic and nitric acids are driven off in the melting of the frit; the chlorides, bromides and iodides are comparatively easily destroyed with the assistance of steam; chromic and manganic compounds, where they are formed, are likewise easily decomposed; the sulphuric acid only offers a stubborn resistance to fusion and to the silicic acid. In some text-books it is stated that the silicic acid expels the sulphuric acid, but this is by no means accomplished so smoothly; the decomposition is complete only in the presence of reducing influences or at a very high temperature, certainly at a temperature, up to which the glazes and frits are usually not heated.

Pelouse has proved that mirror glass melted from sodium sulphate is capable of dissolving up to 3 per cent of sodium sulphate, in the undecomposed condition, without losing any of its transparency. It only showed a slight frost-like opalescence on the surface, which always reappeared some time after being wiped off. A similar peculiarity may also be observed on whiteware glazes, especially such high in lime, and very likely we are dealing here with the same cause. Glazes containing sodium chloride show this effect to a less extent. The solvent power of the glass for sulphates is not always the same, but varies according to the composition of the glass. A bisilicate melted by me, saturated with sulphates, showed a content of 4 per cent of sulphuric acid; a trisilicate melted at the same temperature and under the same conditions, only of 2 per cent. From this it follows that a bisilicate saturated with sulphuric acid, when changed to a trisilicate by taking up silicic acid, discharges 2 per cent of sulphuric acid in the form of sulphurous acid and oxygen. This actually takes place; the glasses which previously had melted clearly, produced on the body, in contact with silica, a blistery coating. This phenomenon is the most common cause of the blistering or "boiling," and if the action is weak, of the roughness (egg-shell surface) of the whiteware glazes. Hence this is a most important fact which explains many phenomena of the blistering, for from the ordinary ingredients of the glaze, the alkalies, oxide of lead, lime, alumina, silicic acid and boracic acid we absolutely cannot deduce any cause of the blisters.

Now, let us see what the source of the sulphuric acid in the glazes is, how it acts and how to overcome its effects, and let us consider separately the sulphates in the glaze, in the body, in the water and in the fire-gases.

I. In the Glaze

The glaze materials always contain greater or smaller quantities of sulphuric acid. The white lead and the lead oxide often contain several per cent of it, especially the red lead. Soda likewise, with perhaps the exception of the so-called ammonium soda, lately used so often, always contains sulphuric acid; the same applies to potash. Potassium nitrate is generally free from sulphuric acid, as well as borax; however, boracic acid always contains a few per cent of it. Sometimes the lime or barium are added as sulphates in the form of gypsum or heavy spar, although this is not only wrong from the technical standpoint, but is also not advantageous economically. In the melting of the frit the calcium and barium sulphates undergo a double decomposition with the alkali salts; there are formed alkaline sulphates, and the lime or barium goes into the glaze. The alkaline sulphates, however, float on top as glass gall in so far as they are not dissolved in the unchanged condition by the frit. Thus a frit saturated with sulphuric acid is always obtained and alkali is lost which is simply washed out. If now the frit is saturated with sulphates and further additions of sand or clay and silicic materials are made, which with the frit form an acid glaze, an expulsion of sulphuric acid and with it an evolution of gases takes place, which causes the glaze to become blistered in all the possible stages. Often a segregation of gall takes place on the surface, which seems to cover it, like a coating of oil, making it dull in appearance. These phenomena are most pronounced when the glaze is burnt in the muffle, and less so in the kiln. This is due to two reasons. First, the burn in the muffle is more rapid, the blisters have not time to come to the surface, to burst there and to fuse down to a smooth coating;

second, in the muffle there prevails as a rule an oxidizing atmosphere, in the kiln; however, there occurs often a periodically reducing condition. The bringing about of a reducing atmosphere is the only reliable means of expelling sulphuric acid from the glaze and removing the phenomena connected with it, a remedy which, however, must be used with caution. By this means the sulphuric acid is easily removed at a red heat, when it is reduced to sulphurous acid, which is volatile, while in the oxidizing atmosphere it is retained very obstinately. In my work I proceed in such a manner, that, when the muffle is heated to a temperature at which the glaze fuses, resinous wood is charged through the peep-hole thus filling the muffle with a thick smoke; this is repeated two or three times. Of course the operation must not be carried out before the glaze covers the colors completely and thus protects them from the reducing gases, otherwise colors sensitive to reducing influences, as pink, antimony-yellow, etc., would disappear. But with the precaution mentioned it will be possible to retain even colors which are easily destroyed by reducing gases. In the use of lead glazes the reduction should not be too intense or too long continued, so that a blacking of the glaze does not take place.

At the same time it must be observed, whether the lead oxide is contained in the lead as such, or whether it is present in the combined state, fritted to a lead silicate. Free lead oxide is much easier reduced to metallic lead by reducing influences, than lead silicate. I have carried out the operation described above with fritted lead enamels on porcelain and always with satisfactory results. The content of sulphuric acid in a porcelain glaze seems to be less dangerous and even harmless. Here the burning is always strongly reducing, and is carried to a high temperature; the sulphuric acid is thus completely destroyed and expelled. For this reason it is permissible to introduce the lime into the porcelain glaze in the form of gypsum, this being advantageous on account of the peculiar molecular constitution of the gypsum. The glaze is thus more easily applied than with the use of marble or limestone.

II. IN THE BODY

The clay used for the production of a body often contains gypsum, iron pyrites or other sulphur compounds. In the washing the gypsum dissolves in water; it is also often transferred to the materials containing magnesia, and produces magnesium sulphate; these salts impregnate the body with sulphur compounds. On storing the material ferrous sulphate is first produced from the iron pyrites, which then enters into a double decomposition reaction with the ingredients of the clay, forming aluminum, magnesium or sodium sulphate. Often the salts thus formed in the body assume such proportions that they appear as visible efflorescence, especially along the edges. How such efflorescence is to be removed has been discussed by Dr. Wilkens last year; it is done with barium chloride, or better, barium carbonate. With the removal of these efflorescences, however, the sulphuric acid itself is not removed from the body; it remains as barium sulphate in a finely divided condition. The sulphuric acid in the body requires for its expulsion, owing to the solid state in which it is present, a much higher temperature than that contained in the glaze. In brick clays which are comparatively fusible, the expulsion, even under reducing conditions, does not take place below silver-melting heat and is effected readily only during the vitrification of the clay. In the relatively more refractory materials of the whiteware and porcelain industry, the expulsion of the sulphuric acid is very likely effected at a correspondingly higher temperature. But in brick clays the sulphuric acid can exist under oxidizing influences, even when the clay enters the state of fusion. For this reason larger quantities of sulphuric acid may be present in the body after the biscuit burn, and is dissolved by the water used in glazing and thus introduced into the glaze. I have always observed that bodies which have been burned in an exclusively oxidizing fire (whiteware) produce a glaze more inclined to be rough (eggshell like) and blistered, than those which have been subjected at a high temperature, above gold-melting heat, to reducing kiln conditions.

But not only the clay itself contains sulphates; these are also introduced from the outside, in working the material. The jollying is done, as is known, in plaster molds, which are easily injured; in molding, small particles of plaster remain attached to the clay, and on sponging are worked into the clay. In addition to this a water solution of plaster from the molds is added to the body. If now these particles of plaster remain in the body, they may produce in porcelain a peculiar phenomenon—pocking. Under oxidizing influences (and pocks are produced only in the oxidizing, never in the reducing, fire) the calcium sulphate may remain undissolved until the body has reached maximum density. Only when fused matter is present in a body does the reaction of expelling the sulphuric acid begin. I have proved this by synthetic experiments, and in fact I do not know how otherwise an evolution of gas in the body could take place in an oxidizing flame. In a reducing atmosphere the sulphuric acid is expelled earlier, before the body has become dense.

III. In the Water

Another source for the introduction of sulphuric acid we find in the water which is used in the preparation of the glaze; this may be especially important for whiteware, but is less so in the porcelain industry, because here some sulphuric acid, especially when it exists finely divided in glaze and body, can be removed by the reducing fire. The sulphuric acid of the water behaves like that contained in the glaze. On removing into a new place, I observed that all the whiteware glazes became blistered so badly that the ware could not be used at all. On close examination I found the cause to be the water used. Old molds had been dumped near the well, which brought to the water a considerable content of calcium sulphate, and especially of magnesium sulphate. On using rain-water the trouble was removed at once. It is important, therefore, to consider the quality of the water used.

IV. From the Fire-Gases

On using coal or lignite the fire-gases contain, as we know, considerable quantities of sulphurous acid. This may be oxidized to sulphuric acid and the water condensed from furnaces has hence always an acid reaction, partly due to sulphuric, partly, if the fuel contains salt, to hydrochloric acid. This water condenses when the kiln and its contents are cold, and often in large quantities in some portions of the kiln, especially in such where the air is stagnant. Owing to the acid constitution of the condensed vapors a peculiar phenomenon is produced,—the striking through of the colors. The acid water condenses on the ware and dissolves most of the colors, for instance, the oxides of cobalt, manganese, chromium, etc., and takes them to the other side of the piece; on the evaporation of the water the coloring metallic oxides are deposited again and thus often there appears a complete reproduction of the outside painting on the inside of the ware.

Finally I would add that sulphates are often taken to the ware by the colors used, if the latter are not sufficiently washed; in this manner roughness or blistering is often produced on the surface, or also complete devitrification, owing to the segregation of glaze gall.

Underglaze Colors and Their Preparation

ALBERT BLEININGER, B.SC., TRANSLATOR

It is evident that only such mixtures or combinations of metallic oxides can be used as underglaze colors for the ceramic industry, which either remain suspended in the glaze in the unchanged condition or which, in partial or complete solution in the fusing glaze, impart to the latter a definite color. In practical work the following metallic oxides are so far being used:

Cobalt oxide, for all shades of blue.
Nickel oxide, for brown.
Copper oxide, for green or bluish green.
Manganese oxide, for brown and violet.
Iron oxide, for brown, yellow or red.
Uranium oxide, for yellow.
Chromium oxide, for green or red.

The noble metals, gold, platinum, and the oxide of iridium for red, gray, and black respectively.

In addition there come into consideration colorless ingredients, which, nevertheless, by their presence produce certain shades with a few of the coloring oxides: Tin oxide, zinc oxide, antimonic acid, alumina, lime, and a few other substances.

The metallic oxides, provided they are pure, produce definite colors under the glaze, which, however, are not the same under all glazes. Not only the higher or lower fusibility of the glaze is a determining factor in this respect, but also the kind of fluxes. Alkalies, lime, lead oxide, boracic acid, etc., affect one and the same underglaze color very differently as far as the shade produced is concerned. For this reason, in the use of colors the composition of the glaze must be considered. But even when knowing the composition of the glaze, owing to various influences, it is not possible to tell what color, or rather what shade, a certain underglaze color will produce. It is solely a matter of trial. If we now mix the coloring metallic oxides we will, in general, obtain colors between those blended; however, if these mixtures have been ignited before application so that they combine chemically with each other they will very frequently show entirely different colors which again vary according to the temperature to which they have been subjected. Also, in the preparation of the color itself, entirely independent of the nature of the glaze, there may be found a cause for the difference in shade. That the intimacy of mixing the separate ingredients exerts a great influence upon the color produced by the mixture of oxides, is self-evident; in this respect much depends upon grinding.

If it is desired, as it often occurs, to obtain a certain shade of color for use in the factory, it is necessary before all things to see that the prescribed mixture contains accurately defined substances of definite composition. I am inclined to reject all those receipts as untrustworthy which deal with ingredients whose chemical composition is entirely unknown. These may have given quite good results at one place, but at another where the same raw materials are not obtainable they will prove entirely unreliable, even when assuming that the preparation of the color is otherwise correct. Substances, for instance, like clay, ochre, chalk, marl, metallic colors, etc., may have a widely differing composition, and the color tints may accordingly be subjected to great variations. It is different when it is said that so much quartz sand, so much alumina, so much pure metallic oxide, so much marble, etc., are to be mixed and after fine grinding to be ignited at a definitely stated temperature. At the same time the use of metallic salts which have a definite composition, which neither lose water in air nor take up any is easily made possible without conflicting with the statement of the receipts.

Furthermore, care should be taken, even when such substances are used as I have indicated, that really chemically pure ingredients are bought, not only because otherwise other coloring components may be introduced, but also such which may injure the desired color. Thus it is always best to use chemically pure metallic oxides in the preparation of colors, or where the commercial metallic oxides are bought to purify them before use. What ingredients may be present in the commercial metallic oxides and which may be detrimental, I shall discuss particularly under the separate oxides. On the other hand if one cannot or does not desire to procure chemically pure substances, the further treatment of the compounds used must aim to render the injurious substances contained by them harmless in regard to color. Furthermore, care must always be taken that such compounds are produced from metallic oxides which prove most resistant to the dissolving action of the glaze. Such a compound is afforded us in the spinel, as Roesler has shown long ago, and it will always be well to make the colors of a similar composition. The spinel proper is composed of one equivalent of alumina and one of magnesia and the most resistant bodies are always obtained when the colors to be produced form similar proportions between a monoxide and a sesquioxide.

After these introductory remarks we can now discuss the coloring metallic oxides themselves.

The cobalt oxide is the underglaze color used most extensively. It is often used as the so-called pure cobalt oxide, R.

K. O., but it also appears on the market in other combinations. The application of the undiluted pure cobalt oxide is not advantageous.

In the first place it is not a pure oxide by any means; it contains other coloring metallic oxides which often tint the blue of the cobalt. Cobalt oxide containing the related oxide of nickel frequently assumes a somewhat gray color. Besides it always contains cobalt sulphide and sulphates in not inconsiderable quantities which give rise to the "boiling" of the painting and which for this reason must be removed. This may be accomplished by an oxidizing roasting of the cobalt oxide, for instance, in the muffle or in the low heat of the decorating fire and subsequent careful washing after grinding. But cobalt possesses a second property which causes difficulties in its use as an underglaze color, namely, that of taking up more oxygen on being heated in contact with air than the blue coloring cobalt oxide contains. At the moment of fusion the excess of oxygen is given off and is very apt to cause bloating of the glaze. The best protection against this danger consists in combining the cobalt with alumina; in this way a blue substance is obtained which is much less sensitive to a continued excess of oxygen as well as to reducing influences than the pure cobalt oxide. The latter as well as the cobalt oxide-alumina compound produce a dark blue color. If a light blue is desired an addition of zinc oxide must be made. The more intense the ignition the lighter it will be. Various tints can be produced from the colors of the cobalt oxide by adding other metallic oxides. An addition of nickel oxide gives grayish blue tints as well as that of iron and manganese oxide, the latter two being less intense in their effect. Uranium oxide acts similarly. By means of chromium oxide, all tints of bluish green can be obtained.

Nickel oxide according to the glaze used and the temperature produces indifferent green, brownish green or brown colors and for this reason is not satisfactory as an underglaze color. Like the cobalt oxide, it must always, before using, be freed from sulphuric acid by ignition and washing after the grinding. It is used chiefly for tinting other colors.

Copper oxide, which is best used as pure copper oxide or as copper phosphate in connection with zinc oxide, can be applied as color only for very fusible glazes. It possesses a disagreeable property inasmuch as the copper molecules have a great tendency at higher temperatures to migrate, spreading widely in the glaze and even penetrating the body. In the whiteware industry it is used as color only in a few cases at a low temperature, and never in the porcelain industry.

The manganese oxide also has disagreeable properties in regard to underglaze decoration. For this reason as the pure oxide it will find but rare application. According to its composition, especially according to the degree of its mixture with iron, it produces brown to violet shades. It has a great tendency to cause defects by the "boiling" of the glaze. This depends, as I have already shown under the heading of cobalt, upon the ease with which it takes up oxygen, forming a superoxide and again expelling it on fusion. It shows this property in a less degree when it is used as color in combination with alumina or with phosphoric acid and tin oxide and also when it is strongly ignited and thus made denser.

The oxide of iron furnishes a large number of brown colors. Used alone as iron oxide or in mixtures and compounds containing the oxide it is quite unstable. In this pure form it can be applied only to very fusible glazes and only to such that attack the color but little; in this manner, when dissolved it gives rise to weak yellow colors. But the iron colors are very stable if compounds of iron and chromium are used. Colors from black through dark and reddish brown to light yellowish brown are thus produced. I would mention here that chromium oxide and iron oxide mixed in equal equivalents and ignited produce a blackish brown which can be changed to a deep black by an addition of cobalt oxide and manganese oxide.

Mixtures with alumina result in a grayish brown color, while an addition of zinc oxide alone gives rise to reddish brown and of zinc oxide and alumina to yellowish brown shades. It will be well to compound the colors after the example of the spinel colors, as I have indicated before, in order to make them more resistant. Since in this way only infusible substances are used, the mixing must be done very carefully; grinding on the mill or under the rubber will be unavoidable and the ignition must be carried as high as possible. The pigments will be of constant color only when ignited very strongly. The heat of the porcelain kiln is best.

Chromium oxide is scarcely less important in the preparation of colors, since, by itself, it furnishes all the brown shades; in mixtures with the oxides of cobalt, nickel and manganese all variations of green; and finally with tin oxide and lime together it produces red tints. In regard to the first few, care must be taken that the mixtures, where in the nature of the case it is admissible, are compounded according to the spinel formula. The red colors show many peculiarities which must be considered. They are obtained when to a mixture of marble and tin oxide a small addition of potassium chromate is made and the mixture is strongly ignited. Outside of the potassium chromate quite a number of substances produce the same effect, but it is safest to work with potassium chromate. However, if too much of the latter is used (over 3 to 4 per cent) the resisting power of the underglaze color is decreased considerably. If silica is added to the mixture the color turns towards red; if the lime is decreased, towards lilac; and excluding the latter from the composition entirely it becomes a pure lilac color. A very strong fire is necessary. Chromium oxide can be used alone or in combination with sand or flux and produces a beautiful green if it is prepared from chromate of mercury by ignition or by heating potassium chromate and sulphur. As to tinting there is to be said that it furnishes olive-green or brownish green with oxide of nickel or manganese and a light green (Victoria green) with calcareous materials, but that contact with ferruginous substances must be carefully avoided since thus brown shades will be invariably produced from the greens. All the green chromium colors become more brilliant when they are burnt in a strongly reducing fire, while the red ones require oxidizing conditions and are destroyed by reduction but renewed on continued oxidation. For tinting to blue, cobalt oxide is used. The colors which are developed by this oxide are essentially dependent upon the temperature to which it is subjected, and by this means they are, in general, made more stable against the action of the glazes.

There remains to be mentioned uranium oxide which likewise produces good yellow colors, which are very sensitive to reducing influences; for this reason their use is attended with difficulties. Additional yellow colors are titanic acid and antimonic acid. The compounds of titanic acid give rise to yellow colors only as crude titanic acid by virtue of its content of iron; with chemically pure titanic acid it is not possible to obtain colors. Antimonic acid becomes a yellow color only when it is combined with lead oxide to a basic salt. If the latter is dissolved by a glaze the color disappears entirely.

The noble metals, of which gold furnishes a very beautiful and stable but expensive pink, platinum and iridium a gray, are always, since they cannot be attacked by the glaze, prepared as silicates with which strong ignition is not necessary.

I have called particular attention to alumina as a means for the preparation of colors since an addition of this substance renders the colors much more stable. I use for this purpose, in most cases, pure alumina, prepared by ignition and washing of the commercial hydrate of alumina and very fine grinding of the same. In any case it will always be a good plan to ignite the metallic oxides used in the preparation of the colors slightly before use and to wash them thoroughly after fine grinding, for only in this manner is it possible to remove the most injurious compounds (the sulphates and also other salts) which cause bloating of the glaze at the places covered with colors, and which not only change the colors, but may give rise to defects by bloating and blistering of the glaze.

The colors used by me, which are the result of a great many practical tests and which have been applied on whiteware and Seger porcelain, under the glaze, when transferred to any other porcelain and whiteware, I am well aware, cannot always be used without any change. But since the mode of their preparation might be of value to one or the other manufacturer who is desirous of making his own colors, the conclusions arrived at are given for the information of wider circles.

In order to render underglaze color-frits applicable to porcelain they have been, as a rule, compounded with 33⅓ per cent of porcelain body and ground very fine. In cases where it is not admissible to make such an addition by means of which they may be applied more smoothly with the brush and take the glaze better, I shall make special mention of it. For the whiteware made by me I have compounded the prepared color frits with 20 per cent of their weight of a whiteware glaze (Na_2O, BaO, $5SiO_2$, $1B_2O_3$) or with 20 per cent of hydrous boracic acid. This mixture was again ignited at a temperature somewhat above the melting-point of gold in order to thus make the colors somewhat denser and more fusible. Where it does not appear necessary to do this I shall make special mention of it. However, in every case it will be sufficient to make the addition of glaze or boracic acid according to needs, that is greater or smaller than I have given it, according to whether the glaze used appears more or less fusible, at least for the purposes of the whiteware industry. This is a matter of practical trial in every case.

In general I have endeavored to prepare the colors as resistant to the solvent action of the glaze as possible. For this reason they possess in most cases, as has already been said above, a composition which corresponds to that of the spinel, *i. e.*, a combination of a monoxide and a sesquioxide because it has been shown in practice that these resist the dissolving action of the glaze the longest. Only where the composition of the oxides does not permit of such a combination or where the shade of color which is desired makes a change desirable, an exception has been made. Finally I desire to say that the finished colors after fine grinding are always washed thoroughly with water in order to remove all the traces of salts which might have been formed on ignition and which otherwise may give rise to bloating of the painted portions.

Black Colors

These are obtained when iron oxide and chromium oxide are combined. Chrome iron, which for a long time has been used as a black color in the decorating of whiteware, has the composition FeO,Cr_2O_3, being a compound consisting of ferrous oxide and chromium oxide. It can be prepared artificially by mixing

	Parts.	
Pure ferric oxide	40.0	greenish black.
Pure chromic oxide	76.2	

The oxides are to be ground wet and most intimately fine on the color mill and after drying and pulverizing in a mortar they are to be ignited at a high heat, best in the porcelain glost fire under reducing conditions and finally to be ground very fine.

If the content of iron oxide is increased, that is, if one takes

	Parts.	
Pure ferric oxide	80.0	brownish black,
Pure chromic oxide	76.2	

a black is obtained with a brownish tinge.

If cobalt oxide is added to this it will assume a bluish black color.

	Parts.	
Pure ferric oxide	80.0	blue-black.
Pure chromic oxide	76.2	
Pure cobalt oxide	20.0	

The three black colors in order to make them easier of application may be ground together with 33⅓ per cent of porcelain body without influencing the shade to any appreciable extent.

Brown Colors

These may be obtained by adding to mixtures of iron oxide and chrome oxide, alumina and zinc oxide.

A dark brown is obtained by compounding

	Parts.	
Pure ferric oxide	80.0	dark brown.
Pure chromic oxide	76.2	
Pure alumina	206.0	

Reddish brown is made from

	Parts.	
Pure ferric oxide	80.0	red-brown.
Pure chromic oxide	76.2	
Pure zinc oxide	194.4	

Light reddish brown

	Parts.	
Pure ferric oxide	80.0	light reddish brown.
Pure chrome oxide	76.2	
Pure alumina	51.5	
Pure zinc oxide	243.0	

Yellowish brown

	Parts.	
Pure ferric oxide	80.0	yellowish brown.
Pure chrome oxide	76.5	
Pure alumina	103.0	
Pure zinc oxide	324.0	

If the addition of alumina and zinc oxide is increased still more, the color is scarcely changed but the mixture is more easily attacked. Since none of the ingredients enter into fusion the oxides in these colors must likewise be ground very fine and intimately in the wet mill; The stronger they are ignited the more resistant will they become.

A beautiful dark brown is also obtained from

	Parts.	
Pure manganese oxide	79.5	dark brown.
Pure chrome oxide	76.2	

A mulberry-brown, suitable, however, only for whiteware (not for porcelain), is obtained by precipitating solutions of 47.4 parts potash alum and 13.85 parts manganous sulphate (cryst.) with a solution of 30 parts of anhydrous sodium carbonate, washing the precipitate well, decanting and igniting at a medium low heat.

Blue Colors

The blue colors are prepared by mixing the oxide or phosphate of cobalt with alumina and zinc oxide. While the pure cobalt oxide is dissolved in the glaze forming a blue transparent body, the colors become lighter but opaque as soon as the cobalt oxide is blended with alumina and zinc oxide and ignited very strongly. The mixture of the oxides must likewise be ground very fine in water.

A dark, very resistant blue which is well suited for the ordinary blue underglaze decoration on porcelain is obtained by mixing

	Parts.	
Cobalt phosphate	183	dark blue.
Pure alumina	103	

The cobalt phosphate is obtained by precipitation from 19.5 parts of the cobaltous chloride or from 40 parts of crystallized cobaltous sulphate in aqueous solution with 53.8 parts of sodium phosphate and 5.3 parts of sodium carbonate, washing and igniting at a low heat.

The mixture is to be ground finely in the wet condition and to be ignited strongly; it will result in a beautifully blue-colored body.

Or there are mixed

	Parts.	
Pure black cobalt oxide	82.8	dark blue,
Pure alumina	103.0	

igniting the mixture.

Lighter blue colors are obtained from

	Parts.	
Pure zinc oxide	20.3	blue.
Cobaltous phosphate	34.5	
Alumina	51.5	

A very light blue is produced from

	Parts.	
Pure zinc oxide	35.5	light blue.
Cobaltous phosphate	8.6	
Pure alumina	51.5	

If it is desired to tint the blue it will be necessary to add a few more oxides. A deep blue approaching a grayish tint is obtained by mixing the oxides of cobalt and nickel.

Equal parts of

Black cobalt oxide and nickel oxide	dark grayish blue,

are mixed and the mixture ignited. A dark bluish green is obtained by mixing

	Parts.	
Black cobalt oxide	165.6	dark bluish green.
Chromium oxide	76.2	
Alumina	154.5	

Strong ignition here also tends to increase the beauty of the color.

	Parts.	
Zinc oxide	40.3	lighter bluish green.
Cobaltous chromate	56.4	
Pure alumina	103.0	

	Parts.	
Zinc oxide	35.5	light bluish green.
Cobaltous chromate	7.0	
Alumina	51.5	

The cobaltous chromate is prepared by precipitation from a solution of 154.8 parts of cobaltous sulphate (anhydrous) with a solution of 97.1 parts of neutral potassium chromate, thorough washing of the precipitate and weak ignition.

Green Colors

Chromium oxide is used as the base for the green colors. In regard to the addition of porcelain body there must be considered that it must be as free from iron as possible, because the beauty of the color is injured by a slight content of iron.

For dark green there are used

	Parts.	
Pure nickel oxide	149.6	dark green.
Pure chromium oxide	76.2	

mixed intimately and ignited strongly.

For chrome green pure chromium oxide is used, obtained by weakly igniting acid potassium chromate with an equal weight of sulphur flowers followed by thoroughly washing or by igniting mercurous chromate.

Lighter green colors are obtained by igniting compounds of chromium oxide with calcium carbonate and fluor spar. The receipt given in Tenax (Proessel) always gave satisfactory results, but I modified it by introducing the potassium chromate always in solution. For this purpose there were mixed

	Parts.	
Potassium bichromate	36	light green. (Victoria green).
Calcium chloride (fused)	12	
Finely ground quartz	20	
Marble	20	
Fluorspar	12	

Quartz, marble and fluor spar are first finely ground and then, after decanting off the water as much as possible, treated with a hot saturated solution of calcium chloride and potassium bichromate, the whole being evaporated to dryness. The dry mass is well rubbed together in a porcelain mortar and then burned at as high a heat as possible. A reducing constitution of the fire-gases gives rise to a more beautiful and brilliant color, while with a continuously oxidizing condition it approaches more the color of the darker chrome green. It also is not permissible to compound the color with porcelain body because on continued oxidizing fire, it would change very easily to a dirty grayish green.

A light yellowish green of another tint is obtained from

	Parts.	
Barium chromate	46	light yellow green,
Marble	34	
Hydrous boric acid	20	

a color which, however, is suitable only for whiteware since it is destroyed at a high temperature. It is to be ignited at about gold-melting heat.

Barium chromate is produced by precipitation from 104 parts of barium chloride with 97.5 parts of neutral potassium chromate. The precipitate is to be washed and slightly ignited.

Red Colors

Red colors are obtained either by preparing the so-called pink, or by means of gold or finally for low temperatures by means of iron oxide preparations.

A fine pink is produced by mixing the following substances:

	Parts.	
Pure ignited tin oxide	50	pink-red.
Marble	25	
Quartz	18	

These are ground by themselves, then treated with a hot saturated solution of three parts of acid potassium chromate and four parts of borax, the solution being evaporated to dryness, well ground in a porcelain mortar and ignited very strongly. Then the red mass is to be ground finely and again washed. The burning must be done under oxidizing firing conditions.

If the quartz is left out entirely and the proportion of tin oxide is increased or that of the marble decreased a more reddish blue tint is produced.

I used for this the following mixture

	Parts.
Ignited tin oxide - - -	70
Marble - - - - -	23

ground very fine as before, then treated with a hot solution of 3 parts of acid potassium chromate and 4 parts of borax evaporated to dryness, well rubbed in a porcelain mortar, strongly ignited, ground very fine and washed thoroughly until all of the yellow color of the solution has disappeared.

If the marble is left out entirely, tints are obtained which approach lilac, but which cannot resist a high heat, like that of the porcelain kiln even if purely oxidizing conditions prevail. However, for whiteware the following mixture is suitable:

Ignited tin oxide - -	50	lilac.
Potassium bichromate - -	3	
Borax - - -	20	

The two last ingredients are also, as before, used in the form of a hot saturated solution, and the mixture is burned after drying at gold-melting heat.

Very beautiful purple and rose tints are obtained by introducing gold as a coloring metallic oxide. A strong purple-red is prepared in the following manner: Of pure white kaolin, best English china clay, 90 parts are worked up in water by boiling and sieving; then 10 grams of gold are dissolved in a mixture of nitric and hydrochloric acids, the solution being freed from excess of acid as much as possible by evaporation on the water-bath. The gold solution is then mixed with the clay slip, sodium carbonate is added till the liquid is distinctly alkaline, and after an addition of about 20 grams of grape-sugar the mixture is boiled strongly for half an hour, water being added to maintain the same volume. Thus a dark purple colored mass is obtained which must be washed and then dried and ignited at a heat not exceeding silver-melting heat. It will in this way assume a somewhat lighter color. A second washing after the grinding of the color is desirable since the first washing is never as complete as is necessary.

A beautiful rose color is thus obtained from

98 parts of white porcelain clay	rose.
2 grams of gold	

Red colors prepared from iron oxide can be used only at a lower temperature and are thus suitable only for whiteware glazing; they must never be burnt above the melting-point of silver.

A good iron-red is obtained in the following manner: 27.8 parts of iron sulphate are dissolved in hot water and by addition of nitric acid, until the iron solution on further addition does not turn darker in color, but remains yellow, being changed to a ferric salt. To this is added potash alum, 189.8 parts.

The two solutions are mixed and precipitated with excess of ammonia, washed thoroughly, ignited weakly and after fine grinding again washed.

Finally there are mixed

	Parts.
Of this red body (iron oxide-alumina) - -	70
Yellow whiteware glaze containing iron - -	30

which are used without further ignition.

Yellow Colors

Yellow colors can likewise be used only in the decoration of whiteware. They are all destroyed in the heat of the porcelain kiln. An intense and brilliant yellow color is obtained from titanic acid, or better titanate of zinc. Either the raw titanic acid is ignited and then ground or it is mixed with zinc oxide by wet grinding.

A suitable proportion is

	Parts.	
Raw titanic acid - - -	41.0	yellow.
Zinc oxide - - - -	40.6	

The mixture must be strongly ignited.

The yellow color of the raw titanic acid, which always contains iron, seems to be due to its iron content; at least it is not possible to produce a yellow color with chemically pure materials. This yellow color is to be used in porcelain painting only when the ware is burned at as low a temperature as possible. If the glaze, owing to overheating, is in a state of strong fusion the color disappears and a dirty gray takes its place. Another fine yellow is obtained from basic antimoniate of lead, and which may be tinted to orange by means of a larger or smaller addition of iron.

A light yellow is obtained from:

	Parts.	
Lead nitrate	73.0	yellow.
Oxide of antimony	33.0	
Pure alumina	12.2	
Salt	100.0	

The ingredients are well rubbed together in a mortar, then fritted at the heat of the whiteware glost kiln, and well washed. If the color is too fusible and disappears easily under the glaze it can be rendered more infusible by an addition of calcium stannate up to 33⅓ per cent. The calcium stannate is obtained by strongly heating

	Parts.
Pure ignited tin oxide	75
Marble	50

ground together in the wet condition. An orange color is obtained by mixing

	Parts.	
Lead oxide	50	orange.
Oxide of antimony	33	
Ferric oxide	18	
Potassium nitrate	25	

The mixture is to be rubbed together, ignited in the glaze kiln, washed thoroughly and, if necessary, like the preceding color, to be mixed with calcium stannate in order to make it more refractory.

A turquoise-blue is obtained from

	Parts.	
Copper phosphate	119.3	turquoise-blue.
Tin oxide	150.0	

The copper phosphate is obtained by precipitation from 37.4 parts of crystallized copper sulphate with a mixture of 35.8 parts of sodium phosphate and 5.3 parts of sodium carbonate, washing the precipitate thoroughly and igniting slightly.

Violet-brown is produced by mixing manganous phosphate and stannic acid in the proportion:

	Parts.	
Manganous phosphate	177.5	violet-brown.
Pure ignited stannic acid	75.0	

Like the copper phosphate, manganous phosphate is prepared by precipitation from 41.6 parts of crystallized manganous sulphate with 35.8 parts of sodium phosphate and 5.3 parts of sodium carbonate, washing and slight ignition.

Fine gray tints are obtained either by dilution of the black colors with soft burned porcelain body or better by mixing the latter with iridium oxide or platinum ammonium chloride. Iridium oxide is the better material furnishing the purest gray. I use as a gray color

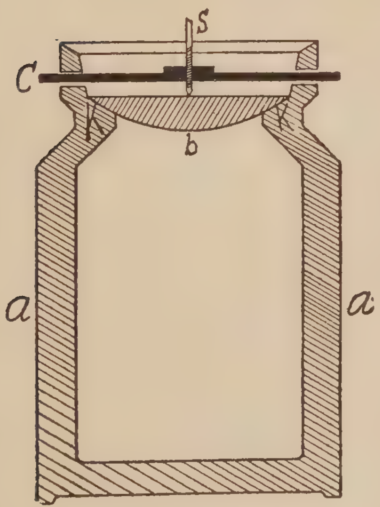
	Parts.
Iridium sesquioxide - - -	5
Porcelain body - - - -	95

These are ground intimately, ignited weakly, at about the melting-point of silver and again ground.

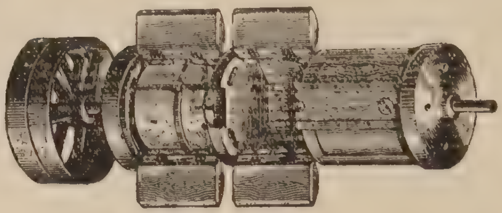
Mills for Grinding Glazes and Colors

ALBERT BLEININGER, B.Sc., TRANSLATOR

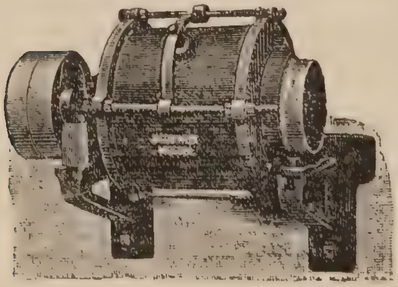
It is often necessary in clay-working establishments that a larger number of small mills must be kept in operation in order to reduce the colors, enamels and colored glazes used, to the required fineness.



Up to the present time there were used, in places where this fine grinding was not done by hand on glass plates with a glass rubber, small mills constructed after the manner of the so-called "blockmills," of porcelain, glass or sandstone, which, however, were difficult to clean, and for this reason were always used for the same color. In the following paragraphs I shall describe a mill which will facilitate, to a very great extent, the work of fine grinding, and which also will not make the necessary cleaning of the apparatus too burdensome a task.



The apparatus consists of a sort of ball mill of porcelain or an equally hard artificial material as, for instance, stoneware. A cylindrical porcelain pot with a lid ground on, and made tight by means of a rubber gasket, is filled with porcelain balls about 2 to 3 cm. in diameter to approximately one-quarter of its volume. The material to be ground is added, stirred to a thin slip with water, and the pot is revolved. In this manner the material to be ground is rubbed to an extremely fine powder by the friction of the balls upon each other and upon the shell of the cylinder. The accompanying figures represent such a grinding cylinder, the kind that is furnished for the purpose designated above by the Royal Porcelain Factory at Charlottenburg. These are made in two sizes, the smaller holding about 2 kg., and the larger about 15 kg. of the material to be ground. Such cylinders are revolved around two pivots in a cylindrical casing made of wooden laths and which, by means of cross boards, is divided into from two to eight compartments; the speed of rotation is about twenty revolutions per minute, a more rapid rotation being undesirable because the balls on the inside, owing to centrifugal force, would be forced against the shell, and would thus take part in the rotating motion. This would put a stop to the grinding action. A mill of this sort is the simplest arrangement which could be imagined.



The cylinder mills sold for some time by the Meissen Foundry and Machine Works are better equipped than the one described above. These consist of a cylindrical wooden shell divided into a number of compartments, which is turned by means of belt and pulley. The cylinder is mounted on a frame or bracket; according to the number of compartments, two to five grinding cylinders are simply placed into the shell and revolve with the latter.

Another illustration shows a mill made by the works mentioned above, which is larger in size consisting of a porcelain cylinder enclosed by an iron shell in which the grinding is likewise accomplished by balls of flint or porcelain. A mill of this description can grind 52 kg.

For many years I have used the kind of mill first described, for the purpose of grinding underglaze colors and colored frits in the experimental laboratory of the Royal Porcelain Factory, and I consider them a complete success. The porcelain pots last very long and were used for years before they had to be replaced. The cleaning of the mills is done simply by flushing the pots and also washing the balls with water; however, since some color is very apt to adhere to the pebbles it is best, on changing the color material, to run the cylinders with a charge of sand for about half an hour and then to wash them again so that no undesired blending of colors can take place.

V. ESSAYS REFERRING TO PORCELAIN

On the Relations between the Composition of Sennewitz Kaolins and Their Behavior on Burning

ALBERT BLEININGER, B.SC., TRANSLATOR

In procuring raw materials for the finer products of the clay industry, be it by mining or by purchase on the market, the manufacturer always endeavors to obtain such materials which have as constant a composition as possible. He does this in order not to be compelled, on changing his supply of raw materials, to experiment by long and expensive trials, and to determine again a new suitable working formula from the new material. For those materials which are furnished by nature in more definite chemical combinations, like feldspar, quartz, limestone, barite, or those which are manufactured by chemical works, like the lead and boracic acid preparations, this requirement is relatively easily fulfilled. In this case it is only necessary to determine whether or not these substances contain impurities which might exert an injurious influence on the quality of the products. Conditions, however, are more complicated in the case of clay material which shows variations not only at different sources, but even in the various layers of the same deposit. On mining the clay material for one's own consumption, only such portions of the deposit are used which are recognized by certain exterior peculiarities and which have been tested as to their properties.

In buying raw materials it is mainly the reputation which certain sources have won which is determinant in the selection and often it is preferred to obtain materials from a long distance at considerable expense and to reject material from near-by as seemingly unsuitable. Owing to the peculiar conditions and the lack of information in regard to the relations existing between the chemical composition of a clay and the peculiarities which it shows in manufacture this was justified to some extent; but it must be the task of science to throw light upon these relations and to remove the restrictions imposed upon the manufacturer in the use of his most important material and to place before him a larger selection of available sources without in any way threatening the success of the manufacture on making a change desired for commercial reasons.

The methods of examining kaolins which have been practiced so far are not suited to furnish even an approximate estimate of their behavior in the process of manufacture and hence practical men have considered chemical analysis as being of less importance than the practical tests made with the materials. In fact, it is impossible for a practical man to form an estimate in regard to the behavior of the kaolin from the figures of the empirical chemical analysis. The latter, though showing the quantitative relations of the separate elementary constituents, gives no information as to the grouping of the same into mineral compounds which show a differing physical behavior, like the hydrous plastic aluminum silicate, the real clay substance and the residue of feldspar and quartz which escaped weathering but have been ground to a fine powder.

Numerical data as it is furnished by the rational analysis which shows the grouping of the elementary constituents of kaolin into its closer mineralogical constituents is without doubt of greater practical importance than the empirical chemical analysis. Not all of the alumina is to be considered in connection with the plasticity of the mass and its ability of being worked, but only that part which belongs to the plastic clay substance; not all of the silica imparts to the body density and stability in the fire but only that contained in the form of quartz; not all the alkali promotes vitrification but only that part which is present in the form of feldspar in the kaolin or the finished body.

The practical tests which are necessary owing to the variations in composition shown by kaolin even in the same deposit, on changing the source of supply though they permit of an estimate as to whether the material may be used without changing markedly the properties of the body in a certain body mixture, do not tell us anything whatever in regard to the manner in which the mixture is to be changed if it is found desirable to retain a kaolin notwithstanding its different composition. The rational analysis, however, informs us in regard to this quite definitely; if it shows an increase or decrease in the quartz content of the kaolin, the quartz addition to the mixture must also be either decreased or increased by the amount brought in by the kaolin; if the kaolin itself introduces feldspar into the body it is evident that the feldspar addition must be decreased by that much in order to maintain a constant body composition. In this way the ordinary chemical analysis may be done away with entirely for practical purposes; since not only the quartz and the feldspar, but also the clay substance possesses a nearly constant composition, as shown by numerous investigations published referring to the pure materials under discussion, all the data necessary for practical work may be obtained from the rational analysis by calculation and with sufficient exactness. Although for theoretical reasons the estimation of the suitability of a certain kaolin for a certain body composition is only permissible according to the results of the rational analysis (in the absence of coarse constituents not washed out which render the kaolin entirely unsuitable), it appeared of interest to compare in a series of experiments the theoretical conclusions with the results of a purely practical test. In this way the correctness of the theoretical deductions could be confirmed and the influence determined which is exerted by a change in composition upon practical phenomena.

The material for examination consisted of fifteen samples obtained from borings made by Mr. Hecker near Sennewitz for the purpose of opening new banks for the Royal Porcelain Factory at Berlin and from which a selection of the china clay which was to be used during the year 1878 was made based on the chemical analyses and practical kiln tests. The rock which gave rise to the formation of the kaolin is porphyry which is exposed as solid rock near the kaolin mines. The kaolin arising from it by weathering is covered by sand and soil and, according to the character of the original rock, is very irregular in its composition, being colored more or less and containing sand. The samples taken for the purpose of investigation in their exterior appearance were such that their suitability for the manufacture of porcelain might at least be considered.

For the investigations described later on there were available only the washed kaolins produced from the raw kaolins; the sand had previously been tested at the Royal Porcelain Factory in an empirical way and had been rejected.

The samples of raw material used in the investigation were treated in exactly the same way as the kaolin which is prepared by washing on a large scale. It was made up to a slip and was washed through a sieve of 900 meshes per square centimeter (this being the sieve used in the Royal Porcelain Factory) and the fine grained portion was evaporated to dryness.

According to the communication by Dr. Sarnow, referring to the burning tests, the sand separated in this way possessed the following properties:

Number of raw kaolin.	Sand washed out.	Character of sand after burning in the porcelain glost kiln.
1	9.0	Quite white, somewhat vitrified.
2	17.5	Fused completely.
3	20.0	Forming a less glossy fusion than No. 2.
4	20.5	As No. 2.
5	23.75	Fused completely, fusion dirty gray with numerous brown spots.
6	8.75	Yellow, especially the finer particles.
7	10.0	As No. 6, but colored somewhat less.
8	13.25	Strongly vitrified, dirty color.
9	18.75	As No. 8.
10	13.0	Like the preceding, but more fusible.
11	12.5	Yellowish, vitrified but slightly.
12	16.75	Quite yellow, but slightly vitrified.
13	13.75	As No. 11.
14	11.25	Quite white, strongly vitrified.
15	12.50	As No. 14.

A behavior similar to that shown by the coarse sand washed out cannot be assumed for the fine sand remaining in the kaolin.

The washed kaolins, properly prepared, after softening and kneading, were molded into tiles with approximately the same content of moisture and in the stiff condition were repressed in a nicely-worked bronze mold into sharp edged tiles, 66 mm. long, 33 mm. wide and 10 mm. thick, their length being determined after drying by means of a vernier rule, reading to 0.1 mm. The burning of the tiles took place in the same saggar in the biscuit burn as well as at the highest heat of the porcelain glost kiln, the trials being set on edge, radially, at an equal distance from the wall of the saggar so that a uniform temperature could be assumed; two tests of the same material were always placed diametrically opposite. The shrinkage measurements in the following table are always the average of four separate measurements of two longitudinal edges of two trial pieces. The porosity measurements were made by weighing the tests in the dry condition, wiping them on the outside after boiling in water for three to four hours, cooling in the water and again weighing. The figures of the table give the quantity of water in grams absorbed by 100 grams of burnt kaolin.

In regard to the determination of the quantities of feldspar and quartz present in the washed kaolin the reader is referred to earlier communications on this subject.

WASHED SENNEWITZ KAOLIN

Number of test.	Composition.				Behavior in the biscuit fire (960° C.—1000° C.)			Behavior in the glost burn.		
	Feldspar.	Quartz.	Clay substance.	Ferric oxide.	Linear shrinkage. Per cent.	Porosity.	Color.	Linear shrinkage.	Porosity.	Color.
1	1.59	33.86	64.55	0.75	0.3	31.7	cream-white	10.2	9.0	light yellow
2	3.24	32.38	64.38	0.92	0.5	30.0	cream-white	11.7	2.6	grayish white
3	2.42	31.13	65.50	0.93	0.5	30.4	cream-white	12.2	2.2	grayish white
4	5.55	29.36	65.09	0.78	0.3	31.5	cream-white	14.2	0.0	bluish white, edges somewhat translucent
5	18.20	32.25	49.55	0.95	0.2	28.1	reddish white	12.0	0.0	bluish white, porcelain like
6	1.21	33.39	65.40	0.73	0.7	31.6	cream-white	10.1	10.0	yello'ish, earthy
7	0.54	34.25	65.11	0.73	0.4	30.2	cream-white	8.3	12.2	light yellowish
8	5.01	36.28	58.73	1.33	0.4	28.8	cream-white	11.8	2.1	grayish white
9	8.64	31.69	59.68	0.79	0.3	28.8	cream-white	12.9	0.0	grayish white
10	8.25	35.15	56.60	0.83	0.3	28.1	cream-white	12.0	0.0	grayish white
11	0.98	33.44	65.58	0.69	1.0	34.0	cream-white	6.0	20.9	yell'wish white, earthy
12	1.30	31.61	67.09	1.11	0.8	30.4	cream-white	9.9	10.3	light yellowish
13	0.53	37.44	62.03	0.59	0.5	31.8	white	4.3	22.0	nearly white, earthy
14	2.14	36.12	61.74	0.63	0.4	31.4	cream-white	11.5	4.1	yellowish gray
15	1.21	38.22	60.57	0.51	0.3	29.1	cream-white	11.4	3.3	yellowish gray

On examining the preceding table there will be observed first a decided variation in the content of unweathered feldspar in different samples, between 0.53 and 18.2 per cent. The presence of quite a large quantity of feldspar which is not removed from the kaolin by washing and which enters the bodies produced from the materials, is already shown by the behavior of the coarse sand, not washed out, indicated in the first table.

The quartz content shows smaller fluctuations which are confined to the limits of 29.36 and 38.22 per cent. The content of clay substance corresponds to the content of feldspar and quartz and owing to its uniform constitution, here assumed, it forms a measure of plasticity. The content of iron oxide, which is embraced by the figures for the clay substance, also fluctuates within very narrow limits from 0.51 to 1.33; this is explained by the fact that only such samples were selected which on inspection appeared to be low in ferric oxide. It is not difficult to determine the relations existing between the results of the analysis and the behavior in burning from the figures determined for the shrinkage, porosity, and degree of coloring.

The shrinkage on soft burning, in which a mutual reaction of the kaolin constituents cannot be assumed, is but very small and hardly exceeds the errors of observation which were made probable in measuring. The porosity also shows but slight fluctuations, and a certain uniformity may be recognized since those trials which contain the smallest amount of clay substance show a smaller pore space and hence are denser than those high in clay substance. This is explained not only from the denser structure, brought about by the presence of the non-plastic constituents, feldspar and quartz, and which is carried to quite a low limit, but also by the greater loss of chemically combined water coordinate with a higher content of clay substance. The color of the soft burned kaolins, according to their content of ferric oxide and the kind of distribution, is in all cases white, tinging occasionally into yellowish and reddish.

The behavior of the kaolin at the highest temperature of the porcelain glost fire is more striking than at the lower temperature. It is found here that the pieces in which the content of unweathered feldspar is very small also possess the relatively slightest degree of vitrification and retain their earthy appearance even at the highest temperatures; at the same time they show only a slight increase in density. It may be assumed that an appreciable action of the mineral constituents infusible at this temperature does not take place, and that a slight content of fluxes, feldspar and iron compounds, does not suffice to begin such an action. The density increases with an increasing content of feldspar, 2 to 5 per cent, and gives to the kaolins a whiteware-like appearance; with a still higher content of feldspar the burnt kaolin assumes more and more the character of hard porcelain. The shrinkage, proceeding simultaneously with the increasing density, stands in an intimate relation to the degree of porosity in the soft burnt state; this is demonstrated by the fact that the mixtures possessing the highest content of clay substance, and hence the greatest initial porosity, show also the greatest fire shrinkage. This phenomenon, of course, is observed only on those trials in which shrinkage has ceased, owing to the complete closing of the pores.

The color which is assumed by the trials in the highest fire appears less as an expression of the iron content (which, however, is still within the limits permissible for whiteware and porcelain) than an expression for the degree of vitrification and hence indirectly of the content of undecomposed feldspar. The color in the most porous samples is the lightest, almost white, while with increasing density it becomes yellowish and with nearly completed shrinkage is changed to yellowish gray and grayish white, and finally into the bluish white of the porcelain. This change undoubtedly is connected with the action of the fused products upon the iron oxide. The pure iron oxide has a red or brown color and is dissolved in glasses producing a yellow color hardly perceptible with smaller quantities. Such a solution of light colored glass must take place more readily in the burning of kaolin, and the color of free oxide of iron must be the more completely destroyed the greater the quantity of the undecomposed completely fused feldspar. The condition of vitrification influences also the state of oxidation in which the iron exists after heating. In the reducing kiln condition the ferric oxide dissolved in the fusing feldspar, as well as that which has not been dissolved, is changed to ferrous oxide. In the latter state, however, a re-formation to ferric oxide may take place on cooling and this will occur in a higher degree the more porous the mass has remained, while in the perfectly dense body the action of the oxygen is at least very much lessened. This is shown quite distinctly by the determination of the ferrous iron in the two samples, Nos. 5 and 6, which, burnt in the same saggar, were exposed to the same influences. After burning in the glost-fire there was contained by

	Ferric oxide. Per cent.	Ferrous oxide. Per cent.
No. 5 - - - -	0.00	0.98
No. 6 - - - -	0.42	0.34

The color which appears on burning the kaolin tiles due to the ferric and ferrous oxide can, hence, not be solely determinant for the estimation of the behavior in the body, that is, after the addition of fluxes. A much more certain indicator for the discoloration, to be expected from the iron content, is offered by the appearance of the sand which has been washed out and which permits us to estimate the more or less uniform distribution of the coloring iron compounds.

According to the method of testing kaolins which now is generally practiced, consisting of burning them in the porcelain glost-fire and judging the appearance of the same, that kind will always appear as the best which remains most porous in burning; it is thus shown to be the whitest and most refractory; even a small content of residual feldspar will cause such a material to appear discolored by causing vitrification, unless the content of feldspar is so high that it brings about a perfect closing of the pores and solution of the ferric oxide. According to this all kaolins which contain a small amount of feldspar are excluded from the start or must be considered of inferior quality, though this may not be true and may not be founded on the facts brought out in actual use. Still the content of feldspar existing in many kaolins deserves consideration from the economic standpoint. In Germany there are used preferably the very refractory kaolins low in, or free from, feldspar; the excellence of many French kaolins, however, especially those of Limoges, may in part be traced back to their high content of feldspar.[1] If a kaolin is otherwise suitable, its content of feldspar is simply corrected by a corresponding change in the body mixture which is readily carried out by an easy calculation.

Thus it would be much more to the point to not subject the kaolins to a burning test, but to burn a body mixture calculated from the results of the rational analysis in which the feldspar and quartz contained in the kaolin are duly considered.

The Composition of Some Foreign Hard Porcelain Bodies

ALBERT BLEININGER, B.SC., TRANSLATOR

Our German porcelain works not only are using domestic raw materials, but in many cases it is believed that certain foreign raw materials are indispensable for successful manufacturing conditions. Often purely economic reasons are at the bottom of this usage and in such cases, where freight rates and cost offer inducements in the use of foreign materials, it is entirely justifiable. On the other hand, the custom is often carried on because it has been established for a long time, and because the manufacturer is afraid to replace the old raw materials with which he is thoroughly acquainted by new ones which might give rise to trouble in manufacture. It is also believed that sometimes the foreign materials possess peculiar properties which are lacking in the domestic materials. This view is especially held with reference to the French kaolins and bodies, much used in German establishments. The manufacturer knows, in a general way only, that these bodies are easily worked and that at a relatively low

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[1] According to an analysis published in the *Thonindustrie-Zeitung* the composition of a washed commercial kaolin from Limoges is as follows:

	Per cent.
Clay substance	55.88
Quartz	5.95
Feldspar	38.27

According to this analysis a German porcelain could be produced from this material by adding only quartz, no feldspar.

heat, with a very fusible glaze, they produce a fine white and translucent porcelain; he also realizes, however, that the quality is often subject to variations. The causes of the different properties which are in favor of the French bodies are, however, not known.

For economic reasons the domestic industry must strive to use its own domestic raw materials and to be as independent as possible of the foreign sources. For this reason an explanation of the properties peculiar to the various bodies should be of great practical interest in order to show to the manufacturer a way of imparting to materials, which are not entirely satisfactory, the desired properties by suitable additions and mixtures without the use of distant and hence more expensive sources.

A journey which I was enabled to undertake, thanks to private support and at the direction of the government, in 1878, to Belgian and French porcelain factories, gave me an opportunity to come into possession of a number of different bodies. The examination and comparison of the latter produced some very interesting conclusions, which, owing to their general interest, are published in the following paragraphs.

The hard porcelain bodies examined were obtained from the following sources:

1. Tableware body from Sévres.
2. Body from J. Pouyat at Limoges (pâte supérieure).
3. Body from J. Pouyat at Limoges (pâte ordinaire).
4. Body from L. Sazerat at Limoges (pâte supérieure).
5. Body from L. Sazerat at Limoges (pâte ordinaire).
6. Body from L. Sazerat at Limoges (body for heavy porcelain).
7. Body from Guérin & Co. at Limoges (pâte supérieure).
8. Body from Guérin & Co. at Limoges (pâte ordinaire).
9. Body from Guérin & Co. at Limoges (pâte de figures).
10. Body from A. Hache & Pepin Lehalleur at Vierzon (pâte supérieure).
11. Body from A. Hache & Pepin Lehalleur at Vierzon (pâte ordinaire).
12. Body of the Société anonyme de céramique at Hal, Belgium (body for heavy porcelain).
13. I } Bodies from the vicinity of Carlsbad.
14. II }

15. I }
16. II } Bodies from Japan.
17. Body of the Royal Porcelain Factory at Berlin.

These bodies were examined by the method communicated by the author in previous essays; the examination was not restricted to the determination of the amounts of the elementary constituents present, but the grouping of the latter into mineral constituents was also ascertained, since these govern the behavior of the bodies on working. These constituents were the clayey bonding material (whose character was noted), the fluxes (feldspar and calcium carbonate), and the main non-plastic ingredient, the quartz.

In a late work on the manufacture of porcelain and whiteware a certain contempt is expressed for this method of examination as being entirely without value for practical purposes, and having originated merely in a scientific whim. However, this did not cause me to drop the views evolved in previous work concerning the constitution of clays and bodies. The investigations now under discussion, on the contrary, are rather adapted to confirm the correctness of the earlier results and to prove their practical value.

The practical man often observes, in calculating body compositions from the chemical analysis of the raw materials, that bodies from different raw materials, though possessing nearly the same total chemical composition, may show a very different behavior in regard to their working qualities in the wet condition, their behavior in drying, and even their fusibility as well as their ability to carry a certain glaze. This is due to the fact that the chemical gross composition possesses only an indirect influence upon the properties of a body and that the latter is governed directly by those characteristic components into which the elementary constituents are grouped. These mineral components with pronounced and tolerably constant properties are the factors which express the properties of the body in the process of manufacture, not simultaneously, but gradually during the various stages of working. The quantity and degree of plasticity of the clayey binding material govern most decidedly the working in the wet condition, turning and molding as well as the shrinking of the body, since the total plasticity is derived from this clay substance; on the other hand, an opposite function is expressed by the total amount of the non-plastic material and in the first stage of working it is more or less immaterial in what proportions the separate non-plastic constituents (quartz, feldspar, calcium carbonate, grog) take part. The proportion of these constituents becomes of importance only during the burning when their quantity and kind and the activity of the fluxes, feldspar and calcium carbonate, upon the refractory constituents of the body, clay and quartz, determine the density of the body, the resulting structure, durability, color, translucency and the ability to carry a glaze.

The practical man, as a rule, will not be able to estimate the effect produced by an increase or decrease of the separate elementary constituents upon the properties of a porcelain body; the success of an alteration may be directly contrary to the desired effect, according to the means which have been employed to bring about the change. To illustrate, the content of silica in a body may be raised by an increase in the quartz content as well as by adding more feldspar, or the alkalies may be lowered by increasing the quartz or the clay component of the body. It will at once be evident to the practical man that the results of these changes differ widely. Although the manufacturer possesses only an indefinite and contradictory knowledge in regard to the influence of the elementary constituents, he will find no difficulty in estimating the effects of the various *mineral* components; he is well acquainted with the effects produced on the body by an increase in kaolin, feldspar, quartz, marble, etc.

By thus grouping the elementary constituents the chemist approaches the point of view of the practical man much closer, for this conception is not derived from a purely theoretical speculation, but it is an eminently practical requirement and, so far, it is the only reliable method of translating the language of purely scientific research into that of practice, though it cannot be denied that the method is still open to a great deal of improvement. The practical man has a clear conception of the terms clay substance, feldspar, quartz, calcium carbonate. In using the term clay substance he may think of finely washed Zettlitz kaolin of which the commercial grades contain 95 to 99 per cent of clay substance beside 1 to 5 per cent of finest quartz which cannot be separated mechanically, but only chemically; in speaking of feldspar he can conceive of pure crystallized feldspar without any sign of weathering or foreign admixture; quartz he may consider as being the pure mineral; calcium carbonate, as being marble, calc-spar, etc. These are conceptions with which every practical man is familiar and which mean more to him than silica, alumina, potash, etc., terms which he can apply only rarely, and then only in a very narrow sense.

Perhaps this may be the place to indicate the defects which still cling to the method of examination proposed as well as the inaccuracies connected with it in order to make proper allowance for them.

The separation of the porcelain bodies into the components clay substance, feldspar, quartz, calcium carbonate depends on the comparatively ready decomposition and solution of the hydrous aluminum silicate, which alone possesses plasticity, and which we call simply clay substance, but which must not be confused with the term clay, and of the calcium carbonate by hot, concentrated sulphuric acid. For a scientifically accurate separation it would be necessary to require that neither quartz nor feldspar are attacked in the least by the reagent. This is undoubtedly true of the quartz, but cannot be said with accuracy of the feldspar. A pure, unweathered Norwegian feldspar, as it is used by the Royal Porcelain Factory at Berlin on treatment with hot concentrated sulphuric acid for about fifteen hours,[1] this being the treatment to which bodies and clays are subjected, showed a content of soluble constituents of 3.59 per cent and a content of undecomposed feldspar of 96.41 per cent.

The soluble part contained:

	Per cent.
Potash	0.55
Alumina	0.62
Silica	2.40

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[1] It has been found later that the digestion with hot concentrated sulphuric acid for fifteen hours is not necessary, and that a treatment continued for one to two hours will suffice. In this manner the errors due to this method of analysis are almost entirely eliminated.

A previous analysis of a feldspar from another source showed a content of soluble constituents of 2.24 per cent, and of undecomposed feldspar of 97.76 per cent.

Although the ordinary feldspar, the orthoclase, is thus proved to be attacked somewhat, yet the loss is not large enough to affect the analytical determination greatly. In using the numerical values obtained, it will be well to remember that owing to the slight solution of the feldspar the results are always somewhat too low; with a high feldspar content of the bodies the feldspar content may be too low by 1 to 1.5 per cent, and that of the clay substance correspondingly high. This correction should be made in calculating the body mixtures from the analyses.

This error is still more increased in practical work if the feldspar used shows indications of weathering, and also if it is intergrown with quartz, which is often the case; in a body mixture calculated according to the analysis the quantity of feldspar introduced must be increased in proportion as it contains clay and quartz.

It is quite possible also that porcelain bodies in place of the orthoclase used in Germany almost exclusively, or together with it, may contain feldspathic minerals which are not so resistant to sulphuric acid, as is the case with the labradorite. In this case, of course, the determination loses much of its accuracy and it must be the task of scientific research to find suitable methods of separation applying to such cases, which, however, do not exist at present. At any rate chemical analysis even here gives valuable data which are useful in practical work, inasmuch as it determines the content of quartz and orthoclase feldspar with sufficient exactness leaving undetermined only how much of the part decomposed by sulphuric acid consists of hydrous aluminum silicate, or of a feldspathic mineral, easily decomposed, replacing orthoclase as a flux. This case is very likely met in the Japanese bodies examined, though it appears that, owing to the low content of soda and lime, the orthoclase is not replaced by labradorite.

After this discussion, necessary for the proper understanding of the following analyses, the numerical results of the investigation are collected in the accompanying tables.

The conclusions drawn from these analyses are interesting scientifically as well as practically: they confirm the assumption made in previous work that in the finer ceramic materials, the kaolin and the white-burning plastic clays, we deal in the plastic component, the clay substance, with a chemically well-defined body. The hydrous aluminum silicate, the clay substance accepted by Forchhammer, having the composition $Al_2O_3.2SiO_2 + 2H_2O$, requires a composition of:

	Per cent.
Silica - - - -	46.33
Alumina - - - -	39.77
Water - - - -	13.90

The composition of the part soluble in sulphuric acid, obtained from the analysis by calculation, with the exception of that of the two Japanese bodies, agrees sufficiently with the above figures to justify the acceptance of the formula given above. The relatively slight deviations are explained on the one hand, as has been shown, by the fact that a slight part of the feldspar is dissolved by the sulphuric acid and is thus considered as clay substance, and on the other hand, the raw kaolin contains small quantities of decomposition products not belonging to the feldspar proper which, however, are also taken in solution by sulphuric acid. To these, belongs especially the ferric hydrate, which is noticed in every raw kaolin, forming yellowish streaks and bands and which is not removed by washing or grinding, but is thus distributed uniformly throughout the entire body.

The portion soluble in sulphuric acid which always contains all of the clayey binding material, showed an essentially different composition only in the case of the two Japanese bodies; the clay substance in these materials possesses a composition ranging between that of the clay substance proper and that of the feldspar, inasmuch as a larger part of the water is still replaced by alkali, it corresponds to a composition similar to that observed in some plastic clays,[1] and also in brick clays, in which the clayey constituent not only is the carrier of plasticity, but also furnishes the fluxes on burning.

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[1] See "The Constitution of Plastic Clays," page 69.

Origin of bodies.	1 Sévres, tableware.			2 J. Pouyat, Limoges (pâte supérieure.)			3 J. Pouyat, Limoges (pâte ordinaire).			4 L. Sazerat, Limoges (pâte supérieure).			5 L. Sazerat, Limoges (pâte ordinaire).			6 L. Sazerat, Limoges (body for heavy porcelain).		
	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.
Silica - -	52.94	22.75	45.17	64.28	44.70	45.47	64.52	45.91	43.75	64.32	44.16	44.23	60.42	37.10	42.66	60.53	35.84	44.59
Alumina - -	28.91	3.05	38.69	23.49	7.18	38.10	22.07	6.63	36.29	23.64	6.55	37.50	26.47	5.09	39.07	26.37	4.45	39.55
Ferric oxide -	0.48	—	0.72	0.87	—	2.03	0.97	—	2.28	0.83	—	1.82	0.52	—	0.95	0.75	—	1.35
Lime - - -	3.99	—	—	1.77	0.85	—	2.10	0.10	3.01	0.86	0.36	1.09	1.37	0.35	1.88	0.69	0.36	0.59
Magnesia -	0.17	—	0.25	trace	—	—	trace	—	—	trace	—	—	—	—	—	trace	—	—
Potash - -	1.70	0.85	1.27	1.11	0.88	0.53	1.35	1.34	0.02	2.66	1.93	1.60	2.75	1.84	1.67	2.95	1.90	1.89
Soda - -	0.68	0.51	0.25	3.07	2.73	0.79	3.13	2.50	1.48	1.82	1.53	0.63	1.60	1.26	0.62	1.44	1.17	0.48
Water - -	9.12	—	13.65	5.48	—	12.80	5.60	—	13.17	5.98	—	13.13	7.19	—	13.15	6.39	—	11.54
Carbon dioxide	2.48	—	—	0.69	—	—	0.57	—	—	—	—	—	—	—	—	—	—	—
Total - -	100.47	27.16	100.00	100.76	56.34	100.00	100.31	56.48	100.00	100.11	54.53	100.00	100.32	45.64	100.00	99.12	43.72	100.00
From this is calculated :																		
Feldspar - -	15.11			36.84			33.84			33.36			26.40			23.49		
Quartz - -	12.05			19.50			22.64			21.17			19.24			20.21		
Clay substance -	66.37			42.05			42.23			45.47			54.36			56.30		
Calcium carbonate	6.47			1.61			1.29			—			—			—		

Origin of bodies.	7 Guérin & Co., Limoges (pâte supérieure).			8 Guérin & Co., Limoges (pâte ordinaire).			9 Guérin & Co. (pâte p. figures).			10 A. Hache & Pepin (pâte supérieure).			11 Lehalleur, Vierzon (body for heavy porcelain).			12 Société anonyme de Hal, Belgium (body for heavy porcelain).		
	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.
Silica	65.61	47.71	45.53	66.00	47.62	42.18	65.79	44.40	44.40	66.97	48.39	45.17	63.48	38.37	44.49	63.95	37.19	45.67
Alumina	23.07	8.10	38.08	22.59	5.87	38.37	23.51	5.06	38.30	20.92	4.98	38.75	25.00	3.18	38.66	25.59	3.17	38.35
Ferric oxide	0.65	—	1.65	0.36	—	0.83	0.31	—	0.64	0.64	—	1.56	0.51	—	0.90	0.60	—	1.18
Lime	0.80	0.73	0.18	1.68	0.30	3.17	1.59	0.54	2.18	2.06	0.15	—	1.06	0.21	1.50	trace	—	—
Magnesia	trace	—	—	—	—	—	—	—	—	trace	—	—	—	—	—	0.54	—	0.94
Potash	2.94	2.29	1.65	2.71	1.70	2.32	2.01	1.13	1.82	2.75	2.22	1.30	2.26	1.12	2.02	2.07	0.88	2.03
Soda	2.72	2.14	1.46	1.80	1.67	0.29	1.73	1.52	0.43	0.41	0.40	0.02	1.19	0.94	0.44	0.98	0.84	2.24
Water	4.50	—	11.44	5.59	—	12.84	5.89	—	12.23	5.43	—	13.20	6.76	—	11.98	6.62	—	11.32
Carbon dioxide	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	100.29	60.97	100.00	100.73	57.16	100.00	100.83	52.65	100.00	100.68	56.14	100.00	100.26	43.82	100.00	100.53	42.08	100.00

From this is calculated :

Feldspar	41.69			30.14			26.01			25.23			16.61			16.02		
Quartz	19.28			27.02			26.64			30.91			27.21			26.06		
Clay substance	39.03			42.84			47.35			40.45			56.18			57.92		
Calcium carbonate	—			—			—			3.41			—			—		

Origin of bodies.	13			14			15			16			17		
	Japanese bodies.						Carlsbad bodies.						Berlin body 1877.		
	I.			II.			I.			II.					
	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.
Silica	74.53	58.91	47.86	71.31	48.90	45.24	66.78	41.48	48.59	65.17	38.99	49.51	63.07	38.09	45.49
Alumina	16.09	5.13	33.58	19.74	1.01	37.82	22.70	3.38	37.10	23.63	4.13	36.88	24.67	4.15	37.38
Ferric oxide	1.03	—	3.16	0.73	—	1.47	0.55	—	1.06	0.51	—	0.96	0.59	—	1.07
Lime	0.06	—	0.18	0.17	0.04	0.26	0.97	0.26	0.02	1.09	0.14	0.11	—	—	—
Magnesia	0.25	—	0.77	—	—	—	trace	—	—	trace	—	—	0.40	—	0.73
Potash	4.37	3.67	5.78	4.04	0.54	7.06	1.07	0.44	1.21	2.92	2.38	1.02	4.25	2.84	2.58
Soda	1.19			0.10	0.07	0.06	1.51	1.32	0.36	0.90	0.79	0.21			
Water	2.83	—	8.67	4.01	—	8.09	6.07	—	11.66	5.98	—	11.31	7.00	—	12.75
Carbon dioxide	—	—	—	—	—	—	0.55	—	—	0.70	—	—	—	—	—
Total	100.35	67.71	100.00	100.10	50.56	100.00	100.20	46.88	100.00	100.90	46.43	100.00	99.98	45.08	100.00

From this is calculated :

	13			14			15			16			17		
Feldspar	26.80			5.20			17.26			21.93			21.56		
Quartz	40.91			45.36			29.62			24.50			23.52		
Clay substance	32.29			49.44			51.89			51.97			54.92		
Calcium carbonate	—			—			1.25			1.60			—		

Another striking fact brought out by the analyses, at least by those of the Limoges porcelain body, is the prominence of the soda content which, in part, is present in larger quantity than the potash, in the feldspar. Since soda feldspar and mixed feldspars are more fusible and produce a clearer glass than the feldspars used in Germany which are of German, Bohemian and Norwegian origin, and which contain as a flux the potash in predominating quantities, this fact together with the higher content of feldspar might explain the pronounced translucency and milk-white color of the French porcelains. In respect to color and translucency, the porcelain of J. Pouyat, at Limoges, ranks first among the bodies examined, and this porcelain has been properly considered by Proessel as being the highest in the scale of such bodies. This porcelain also contains the highest amount of soda.

If we now examine the proportions by weight, deduced from the analyses, between clay substance, quartz and feldspar, we are enabled to divide the bodies examined into four classes:

1. Bodies with a very high content of clay substance but low in quartz and feldspar, in which also the fluxes are supplemented by a considerable addition of calcium carbonate. To this group belongs the body of the Sévres pottery which differs quite considerably from all the other bodies.

2. Bodies very high in feldspar, the content of feldspar exceeding 40 per cent whose fluxing action is intensified in part by a small addition of calcium carbonate while there is present only a moderate quartz and a relatively low clay substance content. To this belong the better bodies of the Limoges and Vierzon district.

3. Bodies with maximum quartz content and a low percentage of clay substance with medium to high feldspar content. This group comprises the Japanese bodies.

4. Bodies with a high content of clay substance representing about 50 per cent and a moderate to low content of quartz and feldspar, the latter being replaced in part by calcium carbonate. This group comprises the bodies intended for heavy porcelain, from Limoges, Vierzon and Hal, the Berlin and the

Carlsbad porcelain, with a somewhat higher quartz content than the preceding.

In order to apply the results of the chemical analysis for practical purposes by calculating the body mixtures from raw materials available to German manufacturers, it will suffice to give a few examples illustrating the method of calculation. In this connection there is to be noted that, according to the results obtained in the chemical treatment of feldspar, as has been mentioned above, a correction is made for the feldspar by adding to the result obtained by direct determination 3.5 per cent, at the same time subtracting the same amount from the clay substance. The analytical data are rounded to 0.5 per cent. These examples will suffice to show how the results of chemical analyses are applied in practical work; of course, in this work it is necessary that the complete mineral analysis of the desired body is known as well as that of the raw materials to be used.

In this manner it is possible, with the assistance of chemical analysis, to produce bodies which possess a certain required elementary composition and are composed of certain chemically and mineralogically defined constituents. The question still remains, whether bodies thus compounded really show the same physical behavior when produced from raw materials of different origin, whether they show the same degree of plasticity and shrinkage on drying and burning. This question, as a rule, must be answered in the negative. These properties depend only indirectly upon the chemical composition, they are functions especially of two factors in the body composition, namely, the fineness of grinding of the non-plastic constituents, quartz, feldspar, marble, grog, and the degree of plasticity of the clay substance. The first factor is governed entirely by the manufacturer and is regulated by coarser or finer grinding of the body; the second is dependent more on local conditions, that is, the available source of kaolin. The clay substance, the hydrous aluminum silicate, in most cases is nearly uniform in chemical composition, at least in most of the purer whitish burning kaolins and plastic clays of the carboniferous deposits, and is presented in two widely differing physical modifications. The one, *a*. Desired to reproduce : Body from Sévres.

Clay substance	66.0[1] per cent	Feldspar	15.5 per cent
Quartz	12.0 per cent	Calcium carbonate	6.5 per cent

Given : Kaolin from Zettlitz, containing .... 95 per cent clay substance, 5 per cent quartz.
Pure ground quartz, containing .... 100 per cent quartz.
Undecomposed feldspar, free from quartz, containing .... 100 per cent feldspar.
Ground marble, containing .... 100 per cent calcium carbonate.

The kaolin is calculated from the following proportion :

$$100 : 95 :: x : 66; \quad x = 69.5.$$

69.5 Zettlitz kaolin	=	66.0 per cent clay substance +	3.5 per cent quartz.		
8.5 quartz	=		8.5 per cent quartz.		
15.5 feldspar	=			15.5 per cent feldspar.	
6.5 marble	=				6.5 per ct. calcium carbonate.
100.0 body	=	66.0 per cent clay substance +	12.0 per ct. quartz +	15.5 per ct. feldspar +	6.5 per ct. calcium carbonate.

b. Desired : Body of J. Pouyat.

Clay substance	41.0 per cent	Feldspar	38.0 per cent.
Quartz	19.5 per cent	Calcium carbonate	1.5 per cent.

Given : Raw materials as before.

The kaolin is calculated from the proportion :

$$100 : 95 :: x : 41.0; \quad x = 43.2.$$

43.2 Zettlitz kaolin	=	41.0 per cent clay substance +	2.2 per ct. quartz.		
17.3 quartz	=		17.3 per ct. quartz.		
38.0 feldspar	=			38.0 per ct. feldspar.	
1.5 marble	=				1.5 per ct. calcium carbonate.
100.0 body	=	41.0 per cent clay substance +	19.5 per ct. quartz +	38.0 per ct. feldspar +	1.5 per ct. calcium carbonate.

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[1] The values given for the composition of the raw materials are taken from earlier investigations and have been rounded to 0.5 per cent; for a special case the composition of the body in question must be known to the one carrying out such calculations.

c. Desired: Body from J. Pouyat, as before

Given: Kaolin from Lettin = 74 per cent clay substance + 17 per cent quartz + 9 per cent feldspar.
Pure feldspar = 100 per cent feldspar.
Pure quartz = 100 per cent quartz.
Pure marble = 100 per cent calcium carbonate.

The calculation of the kaolin requires the proportion:

$$100 : 74 :: x : 41;\ x = 55.4 \text{ parts of Lettin kaolin.}$$

This contains quartz:

$$100 : 17 :: 55.4 : y;\ y = 9.4 \text{ parts quartz.}$$

and feldspar:

$$100 : 9 :: 55.4 : z;\ z = 5.0 \text{ feldspar.}$$

Thus:

55.4 Lettin kaolin	=	41 per cent clay substance +	9.4 per cent quartz +	5.0 per ct. feldspar.	
10.1 quartz	=		10.1 per cent quartz.		
33.0 feldspar	=			33.0 per ct. feldspar.	
1.5 marble	=				1.5 per ct. calcium carbonate.
100.0 body	=	41 per cent clay substance +	19.5 per cent quartz +	38.0 per ct. feldspar +	1.5 per ct. calcium carbonate.

d. Desired : Japanese body I.

Clay substance .... 31 per cent Quartz .... 41 per cent
Feldspar .... 28 per cent

Given : Halle kaolin = 64 per cent clay substance + 36 per cent quartz.
Ebernhahn clay = 86 per cent clay substance + 14 per cent quartz.
Pure quartz = 100 per cent quartz.
Pure feldspar = 100 per cent feldspar.

In order to increase the plasticity of the body, half of the clay substance (15.5 per cent) is taken from the kaolin, the other half from the plastic clay.

The amount of kaolin is calculated as follows:

$$100 : 64 :: x : 15.5;\ x = 24.2$$ parts of Halle kaolin.

The addition of clay is:

$$100 : 86 :: y : 15.5;\ y = 18.0$$ parts Ebernhahn clay.

Thus:

24.2 Halle kaolin = 15.5 per cent clay substance + 8.7 per cent quartz.
18.0 Ebernhahn clay = 15.5 per cent clay substance + 2.5 per cent quartz.
29.8 quartz = 29.8 per cent quartz.
28.0 feldspar = + 28.0 per cent feldspar.

100.0 body = 31.1 per cent clay substance + 41.0 per cent quartz + 28.0 per cent feldspar.

contained in the purer, less plastic kaolins, represented in its purest form by English china clay and the Zettlitz kaolin when moistened, appears "short" and dries to a loose, porous, readily dusting mass, while the other, appearing in the most plastic kinds of fire-clay, is extremely sticky in the softened condition and dries to a hard, dense and bone-like mass. In the first modification the main part of the shrinkage takes place during the burning, in the second during drying. Between these two extremes, the short, but slightly plastic kaolin clay substance and that of the extremely plastic, soapy clays, there are a series of intermediate stages which represent the bonding material of the plastic kaolins and more or less that of the fat, plastic clays, neglecting entirely the fluctuations in plasticity brought about by admixtures with non-plastic constituents. The intermediate stages of the clay substance, in regard to its degree of plasticity, are due to a mixture of these two modifications which, though chemically the same, differ in molecular character.

The larger the content of non-plastic constituents which have been introduced into the body, the more plastic must be the clay substance of the clay used in order to maintain the working quality absolutely necessary. For bodies high in clay substance, the manufacturer will hence use a less plastic kaolin, and for such low in clay substance, one whose clay substance is as plastic as possible.

Although according to the present views regarding the composition of porcelain bodies the lack of plasticity due to the low plasticity of the kaolin clay substance cannot be corrected by the use of the real plastic clays, or at least seems a venturesome attempt, yet it might perhaps be considered whether the introduction of plastic clays would not be possible so as to decrease the difficulties of working, at least as far as bodies high in quartz and feldspar and low in clay substance are concerned. An addition of plastic clay to bodies with a low quartz and feldspar content is not necessary, and no essential benefits could be derived from its use.

Of all the bodies examined, it is surprising to note that the highest degree of plasticity is possessed by the Japanese body I, which apparently equals the plasticity of many whiteware bodies, or even surpasses them in this respect. At the same time this body possesses by far the lowest content of clayey binding material, that is, the highest content of non-plastic matter. It is hardly probable that in their composition a true kaolin has been used; very likely a really plastic clay has been employed for a body mixture whose content of clay substance corresponds only to 33 per cent of Zettlitz kaolin could hardly be considered workable while in reality the plasticity is higher than in any of the other bodies. Synthetical experiments in which the content of clay substance, as shown by analysis, is brought in by the plastic Ebernhahn clay, without the use of any kaolin, proved that such a body produced a porcelain which softened very strongly in the coolest portions of the glost kiln at the Royal Porcelain Factory and showed the greenish translucency peculiar to Japanese porcelain. On taking half of the clay substance from Ebernhahn clay and the other half from Halle kaolin, a body was obtained which was easily worked, and produced a very white and transparent, although somewhat brittle, porcelain. In communicating these results of experiments conducted on a small scale in connection with the analyses given, I do not intend to recommend the addition of plastic clay to the body unconditionally, but this is intended to serve as an explanation why the Japanese and Chinese porcelains, though so high in silica, as shown by these and older analyses, are worked without offering more difficulties in working than the German porcelains with a far higher content of clay.

In connection with this work it might interest many porcelain manufacturers to know that pegmatite from Limoges is used as glaze on all of the twelve French and Belgian porcelain bodies, it being the rock to which the kaolin deposits of St. Yrieux owe their origin. The pegmatite from St Yrieux is a feldspathic rock intergrown with quartz without the presence of any other mineral constituents. The dense, but slightly decomposed parts of the rock are ground as such to a glaze; the weathered and soft portions of the mineral obtained by surface digging as far as they are pure white in color are ground in mills to a porcelain body without any addition, except in a few places of a little marble. As far as the rock is penetrated by ferruginous veins it is selected by hand-picking; the kaolin washed out by very primitive appliances is made up into a body together with the finely ground harder rock.

A sample of the rather hard pegmatite from the mills of Mr. L. Sazerat at Limoges on analysis was found to have the following composition:

	Total. Per cent.	Insoluble in sulphuric acid. Per cent.	Soluble in sulphuric acid. Per cent.
Silica	76.11	65.21	10.90
Alumina	14.61	11.60	3.60
Ferric oxide	0.66	——	0.66
Calcium oxide	1.44	0.85	0.59
Magnesium oxide	0.42	——	0.42
Potash	2.99	2.11	0.88
Soda	3.03	2.81	0.22
Water	1.23	——	1.23
Cobalt oxide	trace	——	——
	100.59	82.58	18.50

The 11.60 per cent of alumina of the second column correspond to a content of 58.20 per cent of unweathered feldspar.

The composition is thus:

	Per cent.
Unweathered feldspar	58.20
Quartz	24.39
Clayey decomposition products of feldspar	18.50

Some Raw Materials of the Limoges Porcelain Industry

Albert Bleininger, B.Sc., Translator

The French porcelain industry is centralized near the rich deposits of raw material of Limoges which form the foundation of this industry, just as has been done in Thuringia and in the Carlsbad district. This crowding together of many similar establishments has given the place a peculiar character.

The Limoges porcelain is considered the best, not only in France, but it is also esteemed highly in Germany, and by many German manufacturers it is set up as the technical ideal which they strive to attain; it is claimed that the French porcelain can not be equaled, since in Germany such excellent raw materials as the kaolin from St. Yrieux and the pegmatite are lacking. The porcelains of Limoges excel not only in lightness and elegant shape and in the tasteful decorative treatment peculiar to the French, but the body differs from most of the German products also in a purer, more agreeable color, its thinness and greater translucency. The superiority of the Limoges porcelains, as far as body and glaze are concerned, is undoubtedly first of all founded on the character of the raw materials available. For this reason it was desired to obtain possession of a few of the raw materials used at Limoges in order to examine them from the point of view developed in some earlier work and we communicate the results of this investigation, which brings out some interesting facts, in the hope that it may indicate to the German porcelain manufacturers how to strive toward the production of similar ware with German raw materials.

We have shown in earlier investigations that of the raw materials which usually serve for the production of hard porcelain, kaolin, feldspar and quartz, the latter two are already present in the kaolin in varying amounts according to the different deposits of kaolin and the degree of its washing. It has also been shown that the variation in the chemical composition of the kaolin is due to the varying amounts of these components, while the main constituent, the clay substance (hydrous aluminum silicate), produced by the decomposition of feldspar, is nearly alike in composition in different kaolins, and we presume that very likely it possesses nearly always the same properties.

The art of compounding porcelain bodies comprises the addition of certain amounts of feldspar and quartz necessary for certain purposes to kaolin, as far as they are not present in the latter naturally. This artificial incorporation is accomplished either by including in the body mixture, quartz or feldspar, or both, or adding to kaolins very low in quartz and feldspar, china clays more or less high in quartz and feldspar. Owing to the wide fluctuations shown by china clays in regard to the quartz and feldspar content in every deposit, or rather in every shipment, a different proportion of the artificial component is necessary.

The ordinary chemical analysis, which considers only the percentages of the elementary constituents, does not show how much of the silica belongs to the clay substance, how much to the feldspar, and how much to the quartz, although in each of these forms the silica possesses widely differing properties; likewise it gives no definite data as to the amount of alumina belonging to the hydrous silicate and that going with the feldspar, etc. The rational analysis, on the other hand, determines with an accuracy which suffices completely for all technical purposes the mutual relations between the alumina, the feldspar and the quartz in the china clay or body. With the help of the ordinary means of chemical analysis, fluctuations in the composition of these constituents may be determined. It permits us to trace, in the clays as well as the bodies, the properties which are connected with the fluctuating content of the mineralogically and physically different components.

The Limoges materials were considered from this standpoint.

I. Kaolin from Limoges

	Gross analysis. Per cent.	Decomposed by sulphuric acid. Per cent.	Not decomposed by sulphuric acid. Per cent.	Composition of the clay substance decomposed by sulphuric acid. Per cent.
Silica - -	58.39	32.22	26.17	47.09
Alumina -	27.52	7.49	20.03	36.04
Ferric oxide -	0.36		0.36	0.64
Lime - - -	1.52	4.40	1.82	3.27
Magnesia -	0.41			
Potash - -	1.71			
Soda - -	2.58			
Loss on ignition -	7.19	7.19		11.94
	99.19			

The composition of the kaolin, assuming that the feldspar contained by it corresponds to the acidity of orthoclase, is calculated to be

	Per cent.
Clay substance - - -	55.88
Quartz - - - -	5.95
Feldspar - - - -	38.17

On comparing these figures with those obtained from a number of German and Austrian kaolins examined, a great difference will be observed. While in the latter the non-plastic materials often amount only to a small part of the body as in the Zettlitz kaolin and the Pilsen china clays, and again frequently consist of finest quartz dust which cannot be washed out as in the clays from Sennewitz, Kaschkau and Lettin, in the case under discussion the non-plastic matter is composed largely of fragments of undecomposed feldspar. It is obvious that thus the kaolin assumes a widely different character, and this explains why Brogniart, in giving the composition of the Sévres body, mentions that no feldspar is added but only sand; since the kaolin is naturally high in feldspar, an artificial addition of the latter is, of course, not necessary. The kaolin which is worked at Sévres is also obtained from the Limoges district and very likely has the same composition as that examined.

The composition of the real clay substance corresponds nearly to that which is represented by a number of German china clays, and owing to its higher content of alkali and lower percentage of water it perhaps approaches that of the so-called plastic clays examined by us.

II. Porcelain Body from Limoges

This on analysis was found to have the following composition:

	Gross analysis. Per cent.	Not decomposed by sulphuric acid. Per cent.	Decomposed by sulphuric acid. Per cent.	Composition of clay substance. Per cent.
Silica - -	66.71	47.27	19.44	45.35
Alumina - -	21.58	5.93	15.65	36.50
Ferric oxide -	0.47		0.47	1.09
Lime - - -	0.61			
Magnesia - -	0.37			
Potash - -	2.93	3.76	1.77	4.13
Soda - -	1.62			
Loss on ignition -	5.54		5.54	12.92
	99.83			

The composition of the porcelain body is hence

	Per cent.
Clay substance - - -	43.04
Quartz - - - -	26.46
Feldspar - - - -	30.50

The composition of the clay substance unlocked by sulphuric acid thus checks fairly accurately with the figures calculated from the kaolin analysis.

It appears that the body is higher in quartz and feldspar than for instance the Berlin porcelain body, and this explains its greater translucency as well as the greater fusibility. The latter is also essentially influenced by the nature of the fluxes which in the German porcelains consist principally of the relatively least fusible potash, while the Limoges body shows a very high content of soda, lime and magnesia.

III. GLAZE FROM LIMOGES

This glaze shows the following composition:

	Gross analysis. Per cent.	Not decomposed by sulphuric acid. Per cent.	Decomposed by sulphuric acid. Per cent.
Silica - - -	74.99	70.92	4.07
Alumina - - -	14.80	12.38	2.42
Ferric oxide - -	0.37	——	0.37
Lime - - - -	1.09	0.20	0.89
Magnesia - -	0.36	0.36	——
Potash - - -	4.31	7.17	0.68
Soda - - -	3.49		
Loss on ignition - -	0.65		0.69
	100.06		

These figures coincide with the data given by Salvetat in regard to the composition of pegmatite, which as in Limoges is also used at Sévres. The pegmatite is a variety of granite in which the mica has almost completely disappeared and only the quartz and feldspar are left behind. On account of the markings on the fracture which resemble Hebrew writing caused by the intergrowing of the feldspar and quartz crystals it is also called scripture-granite. The analysis shows that the pegmatite used as glaze is undergoing weathering and contains about 9 per cent of clay. On calculating the content of feldspar, in the unweathered portion, from the amount of alumina, according to the principles stated earlier, the glaze is found to have the following composition:

	Per cent.
Clay substance	8.93
Quartz	26.49
Feldspar	64.58

According to the amount of alkalies found in the glaze the feldspar is to be considered as being composed of equal parts of potash and soda feldspar.

The Wegeli Porcelain Bodies

Albert Bleininger, B.Sc., Translator

As has been reported at an earlier date, some quantities of porcelain body have been found in the work of excavating for the cyclorama at Berlin on the premises of 26 Neue Friedrich Strasse, which, according to all indications, originated from the Wegeli porcelain manufactory which was closed in 1757. The bodies are partly shaped into balls of about twenty pounds weight, and were found buried between mats and boards about 2 meters beneath sand and débris; partly they were found in irregular piles, separated from the layer of sand only by blankets.

Since it is probable that the Wegeli factory, the predecessor of the Royal Porcelain Factory, occupied the premises 26 Neue Friedrich strasse, there can be no doubt that we have to deal here with some old Wegeli body which perhaps has been buried on the closing of the factory in order to secure the arcanum, or to keep it for use in case of resuming the manufacture.

It seemed of interest to subject these bodies to an examination: On the one hand to determine, whether and in how far the bodies used in the first porcelain factories differ from the ones used to-day; on the other hand, whether it would not be advisable to return to the original body composition. The total quantity of the body collected amounted to about 60,000 pounds. This was hauled away by the Royal Porcelain Factory, and will, after preceding washing (it being rendered impure by rotten wood, remnants of blankets and sand), be preserved for special purposes.

The main quantity of the body found (body No. 1) is formed into balls, as they are still at the present time furnished to the turners. It is very white and but little plastic. Its rational analysis gives the following results:

	Per cent.
Clay substance	81.55
Quartz and feldspar	18.45

The sandy residue (quartz and feldspar) gave:

	Per cent.
Silica	12.59
Alumina	3.91
Lime	0.56
Potash	0.52
Soda	0.87
	18.45

On calculating the feldspar content from the content of alkali, lime, potash, and soda, the following result is obtained:

	Per cent.
Feldspar	17.28
Quartz	1.17

Body No. 2 was found in irregular heaps, was likewise very white, but little plastic. It consisted of:

	Per cent.
Clay substance	84.96
Quartz and feldspar	15.04

The sandy residue consisted of:

	Per cent.
Silica	10.37
Alumina	2.63
Lime	0.77
Potash	0.46
Soda	0.81
Total	15.04

On calculating the feldspar from the alkali content, this gives 17.48 per cent, thus more than the quantity found by direct determination.

Body No. 3 was likewise found in irregular heaps and only in slight quantity. It was of a reddish color, but little plastic.

It consisted of:

	Per cent.
Clay substance	81.37
Quartz and feldspar	18.63

The sandy residue consisted of:

	Per cent.
Silica	13.50
Alumina	3.56
Lime	0.52
Potash	0.40
Soda	0.65
Total	18.63

From the alkali content there was found by calculation:

	Per cent.
Feldspar	13.10
Quartz	5.53

Besides these bodies there was found a washed clay (No. 4) very likely the Auer clay used then in the Meissen factory (in the beginning used exclusively by all the porcelain factories) whose deposits are now exhausted.

This contained:

	Per cent.
Clay base	96.19
Quartz and feldspar	3.81

The sandy residue consisted of:

	Per cent.
Silica	3.04
Alumina	0.55
Lime	0.07
Potash	0.08
Soda	0.07
Total	3.81

From this is obtained:

	Per cent.
Feldspar	1.72
Quartz	2.08

No. 5. Raw clay.—This was very white and contained many

fragments of quartz. After washing out 50 per cent there remained in the part washed off:

	Per cent.
Feldspar	88.72
Quartz and feldspar	11.28

The sandy residue consisted of:

	Per cent.
Silica	6.75
Alumina	2.70
Lime	0.85
Potash	0.27
Soda	0.71
Total	11.28

From the amount of alkali a feldspar content of 16.29 per cent was calculated, which is likewise more than has been found by direct determination.

What makes the composition of the bodies such a peculiar one is the low potash and the high soda and lime content in the feldspar, which is present in the bodies. This indicates that not an orthoclase feldspar which is now being generally used in the manufacture of porcelain, but probably an oligoclase feldspar with lower silicic acid content, was employed.

This would explain the fact that in the bodies Nos. 2 and 5, a higher feldspar content was calculated from the content of alkali than was actually found. Although the question as to the feldspar used is as yet an open one, we can still draw with certainty, from the analysis, the fact that no quartz intentionally entered the body composition, for the slight quantities of 1.15 up to 5.53 per cent of quartz are derived without doubt from the china clay used, in which 2.08 per cent were found, and that the body was thus simply composed of from 15 to 18 per cent of feldspar, and 82 to 85 per cent of China clay.

To this corresponds also the behavior of the bodies in burning. They shrink more than the Berlin body, show great tendency to warp, and to bring out the molding seams prominently, burn to a cream color, and are less transparent, but considerably whiter, than the products of the following manufacturing period under Gotzkowsky and at first under the government, before the Halle clay now used, was discovered. These properties are shown also by many Meissen products of that time. Our present bodies have all a higher or a lower quartz content which fluctuates between 20 and 45 per cent, and where the quartz is not already contained in the kaolin as in the Sennewitz clay, which contains about 35 per cent of it, an addition of quartz is always given to the body. This had apparently not yet been done in the oldest process of manufacture, and to this are due the defects of the Wegeli porcelain examined. How it was possible for Wegeli to obtain the Auer clay we are not enabled to state. It is very unlikely that it was brought to Berlin before the Silesian wars, of which the second was being fought, as is known, between 1744–45, since Wegeli commenced with the fitting up of his factory only in 1750; at any rate the fear of not being able to replenish his stock of porcelain clay, might have been the reason for the second closing down of the factory, which at the time seemed incomprehensible to the contemporaries. It is known that Gotzkowsky had worked with Passau clay.

Colored Porcelains

ALBERT BLEININGER, B.SC., TRANSLATOR

If we ask why colored porcelain glazes, that is, colored coatings melted on in the glost-burn are applied only by so few factories, this question can be answered in three respects.

In the production of pottery, figures and bric-a-brac, it is endeavored to retain the white color of the porcelain, thus excluding every coloring metallic oxide from the glaze or the body—on the one hand, because we are accustomed to retain the whiteness of the porcelain as much as possible, and on the other hand, in consideration of the subsequent decoration with muffle colors. Again, considerable technical difficulties are offered in the production of such colored coatings, which without doubt are greater than those found in the production of similar glazes on whiteware and faience. These difficulties are to be found in the management of the burning, which, owing to the high temperature of the porcelain kilns, and to the alternately oxidizing and reducing constitution of the gases, is not easily controlled. For this reason it is difficult to produce certain colors and be sure of results. Besides, the number of coloring metallic oxides which could be practically used at the high temperature of the glost-burn in question is only small, the color scale is limited and the products show a certain monotone.

The glazes commonly used on porcelain, in whatever proportion they may be compounded from kaolin, quartz, feldspar, porcelain body, etc., have in general the formula

$$RO, + (1\text{–}1.25)\ Al_2O_3 + (10\text{–}12)\ SiO_2,$$

that is, with reference to the fluxes, usually potash and lime, as unity, they are ten- to twelvefold acid silicates. The lower values correspond to about the soft French porcelain, the higher to our German hard porcelain.

There are only two ways of producing colored glazes from the colorless ones, either by adding simply coloring metallic oxides to the glaze, or substituting for the colorless fluxes, potash and lime, coloring metallic oxides in equivalent proportions.

The first method is applicable only when the metallic oxides added possess a strong coloring power, so that they need be added only in small quantities because they are fluxes and would change the normal formula given above considerably. The consequence of the addition of coloring metallic oxides is crazing of the glaze, which is more pronounced on porcelain, since it is generally accompanied by a shelling off of the glaze from the body. The second method is the more proper one, inasmuch as by it the normal formula is not changed, and hence crazing cannot appear. But as the quantity of replaceable colorless fluxes is only slight, amounting according to whether the flux is lime or potash, only from about 8 to 11 per cent, a narrow limit is set, especially since only a part of the colorless fluxes can be replaced by coloring ones.

Again, the fact operates against the use of colored glazes for hard porcelain, that the latter is burned in the reducing fire and that it is almost impossible to finish burning it without the application of a reducing flame. Thus a number of metallic oxides which are easily reduced are excluded from this use, and those which remain, cobalt oxide, chromium oxide, iron oxide, manganese oxide, as well as the noble metals, gold, platinum and iridium, represent but a narrow scale of colors.

The conditions, however, are different and a good deal more favorable on leaving the difficultly fusing glazes of the hard porcelain and going over to the more fusible ones of the Seger porcelain. The normal formula for the glaze of the Seger porcelain, which consists of the same materials as the glaze of the hard porcelain, is as follows:

$$RO + 0.5\ Al_2O_3 + (4\text{–}6)\ SiO_2$$

The glaze is thus only a four- to sixfold silicate, referred to the colorless fluxes.

Thus for the substitution of the latter by coloring metallic oxides a much wider limit is left; that is, a larger amount of coloring oxide can be introduced into the glaze with injury, without producing a dimming of the glazes owing to the segregation of metallic oxide, which appears so easily in hard porcelain glazes. The main advantage of these glazes consists in the fact that they can be burned in the oxidizing fire; owing to this advantage the copper oxide, nickel oxide, and uranium oxide, can be added to the above list of metallic oxides, so that the color scale is enriched by green, brown and yellow colors. Other neutral colors may also be applied, which proceed from the mixture of white glaze with pinks of different composition, which furnish a series of red and pink shades. If in producing these colored glazes there are introduced into the glaze in place of lime, equivalent quantities of monoxides, cuprous oxide, nickel oxide, cupric oxide, and for alumina, the coloring sesquioxides, chromium oxide, ferric oxide, manganese oxide and uranium oxide, there is obtained a color-scale whose members not only possess the same chemical character, but also possess nearly the same melting-point, thus permitting of burning in one fire. The colored glazes can also be blended at pleasure and so give rise to a very extensive scale of colors.

The Composition of a Biscuit Body

ALBERT BLEININGER, B.SC., TRANSLATOR

We know that porcelain bodies which are used for the production of unglazed biscuit figures, frequently show a certain fatty gloss on the surface, especially when receiving a very hard firing, and hence are less agreeable in appearance. This gloss appears on the busts and small figures made from it, especially prominent on those places which project from the main portions, that is, principally on the finger points, the nose and the hair parts. In a fine biscuit body such glossy places should not exist. A select beautiful biscuit body not showing this fault, very likely a Copenhagen product, was made the object of an examination by me.

The body had the exterior appearance of frit porcelain; it was extraordinarily transparent so that the light entered it to a certain depth, showed an entirely matt surface with a conchoidal and very glossy fracture, and in no place the objectionable fatty gloss; its coloration was of a slightly yellowish cast of an agreeable shade.

The chemical analysis of the body was found to be as follows:

	Per cent.
Silica	63.00
Alumina	24.74
Ferric oxide	trace
Lime	0.77
Magnesia	0.64
Alkalies, especially potash	10.86
Total	100.01

The extraordinary high content of potash, as a rule not rising to such a height in porcelain bodies, and the low content of silica gave rise to the supposition that the porcelain body used for it is composed of a mixture of kaolin, free from quartz, and feldspar. In fact, by calculation from the theoretical composition of the feldspar and pure kaolin, a composition of 68 per cent of feldspar and 32 parts of kaolin is obtained, leaving nothing for the quartz content of the body. Whether the slight content of lime originally belonged to the feldspar used or was added intentionally (as about 1 per cent of marble or calc spar) could not be determined, and would also not be of great importance, owing to the small amount of lime. Such a body, from 68 parts of Swedish feldspar and 32 parts of Zettlitz kaolin, proved to be much too high in flux for the heat usually applied in the porcelain industry. At the temperature of cone 6 it already had assumed the character, shown by the sample piece; at cone 8 it went completely into fusion, but retained its dull surface. A body of the composition of 65.5 feldspar, 1.5 marble, and 32 Zettlitz kaolin showed the same properties.

It was now tried to produce the same body, but with a lower feldspar content, in order to render it more difficultly fusible and to compound it with different clays, and it was observed that a body of equal beauty can be produced only with kaolins free from quartz. When kaolins containing quartz were used, for instance Loethain clay with 20 per cent of quartz, or Halle kaolin with 35 per cent quartz content, there were always produced bodies which showed more or less the disagreeable fatty gloss on the surface. For the temperature of the Seger porcelain kiln (cone 8 to 10) at my disposal, the following mixture was found best suited for the production of similar biscuit ware: 45 parts of Swedish feldspar, 54 parts of Zettlitz kaolin and 1 part of marble. In order to diminish the tendency of the body to show raised seams, a part of the body was burned in the glost burn, ground, and then again compounded with the above body in the proportion of 30 to 70 parts. The biscuit figures thus compounded showed extraordinary beauty, similar to fine-grained marble, and this suggestion referring to bodies free from quartz should prove of interest to many interested parties.

Japanese Porcelain, Its Decoration, and the Seger Porcelain

ALBERT BLEININGER, B.SC., TRANSLATOR

The technique of the decoration of the Chinese and Japanese porcelains differs materially from the methods of decoration applied in Europe, especially in one respect. In the first, beside usually dull colors, fixed by means of a flux, transparent, more or less relief-like, colored glasses, and often enamels made opaque by tin oxide or alumina are preferably applied, while we use enamel colors exclusively. These enamel colors are formed by metallic oxides or metallic salts, not readily attacked by glasses, which according to the nature of the colors are compounded with colorless glasses, consisting of alkalies, lead oxide, bismuth oxide, silicic acid and boracic acid in different proportions, in such a manner that the glasses fix the mineral pigments on the body at a moderate heat and give to the color a certain gloss, without, however, dissolving the coloring bodies themselves. But the painting thus effected, for which, owing to the low burning temperature, a very rich scale of colors was created, does not prove very durable; many of the glasses used for the fixing of the colors are not only very soft, but also are attacked by acid fluids.

In place of these enamel colors there often appear on Chinese and Japanese porcelains, real translucent colored glasses, in which the coloring metallic oxides are not suspended in the fluxion, but are dissolved in it. The use of such transparent glasses as a means of decoration, which are not applied like the enamel colors in extremely thin layers, but in relief-like coatings, has to contend with insurmountable difficulties in the manufacture of European porcelain, at least in the hard feldspar porcelain, while its application on soft porcelain, ivory porcelain, English bone china, French frit porcelain and similar products, which are provided with lead glazes, similar to whiteware glazes, seems more warranted. The use of transparent colors give to the Asiatic porcelains a peculiar charm and is one of their characteristics.

The enamel colors used by us often crack when applied in thick layers, especially when exposed to a high long-continued or repeated muffle heat; they then shell off from the body. This is true of all colored transparent enamels, applied in thick layers in a still higher degree. On European porcelain they usually not only shell off completely, but also crack off the glaze and burst deep holes into the body, while on the Chinese and Japanese porcelains there sometimes appear fine crazes in the glaze, but never a shelling-off of the coating.

For this difference in the behavior of the Asiatic and European porcelain, in regard to the easily fusible glazes, an explanation must be found in the composition of the bodies and glazes, for it seems incredible to suppose that in one continent the same product, composed of materials from the most various sources, should have materially different properties in another region of the world, while both the Asiatic and European bodies and glazes show in general a similar behavior among themselves.

From earlier investigations communicated in the technical literature, two things may be deduced in reference to the bodies used in the porcelain industry. The bodies of Chinese and Japanese porcelains show, on the whole, a greater content of silica, and the glazes a greater content of lime, than the European. In how far the first condition can influence the fusibility as well as the other properties of the body, cannot be determined from the earlier examinations, as from them the grouping of the elements into mineral compounds, which in different combinations have different chemical and physical properties, cannot be deduced. But the glazes are, as was to be expected from the analysis, and also has been proved by Salvetat, much more fusible than those used in Europe for hard porcelain.

The examination of a number of kaolins, white burning clays, green porcelain and whiteware bodies, which I have carried out and published in the last years, has now determined that the portion which is decomposed by sulphuric acid and which at the same time gives to the body its plastic property, always has nearly the same composition. This could be proved for a great number of clays without exception. The composition corresponds in all of them to the formula established by Forchhammer for the decomposition product of feldspar,

$$Al_2O_3\ 2SiO_2 + 2H_2O,$$

and so completely that the plastic portion must be acknowledged to possess this composition. Between the plastic part of the kaolins and that of the real plastic, soapy clays, there is a difference only in so far as the constantly present content of alkalies is somewhat greater in the plastic clay substance (2 to 5 per cent) and somewhat smaller in the kaolins (1 to 2 per cent) and that, in consequence, the content of water in the first is somewhat lower (8 to 11 per cent) and somewhat higher in the latter (12 to 14 per cent).

In the calculation of the analysis of bodies, this fact is of extraordinary importance, because thus the possibility is given of determining the more immediate constituents of the porcelain bodies, which decide their properties, clayey bonding material, feldspar, quartz, or calcium carbonate, if not with scientific exactness, yet with an accuracy sufficient for practice.

As in the determination of the clayey bonding material by dissolving in hot concentrated sulphuric acid many varieties of feldspar are likewise attacked somewhat and their ingredients calculated in with the clay base; the figures for feldspar calculated from the analysis are sometimes found to be somewhat smaller and those for the clay base somewhat larger than the true values, but the figures for the quartz and lime content are not influenced by it. From this it follows that in calculating a body composition from the analysis the feldspar content can be taken somewhat higher and the clay substance content somewhat lower.

The fact that I came into possession of three samples of green porcelain body, a few biscuit bodies of egg-shell porcelain and two glazes of Japanese origin, through the kindness of Mr. March, caused me to study the differences existing between the composition of the Japanese and European bodies and glazes. The possibility thus arose of producing porcelain with properties similar to that manufactured in Japan from native raw materials. The porcelain raw materials mentioned originate from a factory in Arita, in the province of Hizen, Japan, and have been collected by Dr. Wagner, in Tokio. In a letter to Mr. March, he gave very interesting details about the process of manufacture, which I quote. According to these the china clay is obtained on the slopes of a round valley in irregular pits as they may be reached most conveniently. It consists of portions of a grayish white porcelain stone rendered soft by weathering. The sorting of the raw china clay, which has the appearance of an impure clay rather than of a raw kaolin formed by the weathering of porphyry or granite, is done according to the color, consistency and fineness of the different qualities. The purest, whitest and most plastic is worked into thin-walled porcelain (egg-shell porcelain); for ordinary porcelain the clay is mixed with an inferior quality. A further addition of other materials, for instance, feldspar and sand, as it is done in European porcelain factories, does not take place; the partially weathered stone contains all the ingredients for the production of porcelain.

The clay thus won is broken up, finely ground in very primitive stamp mills with addition of water and washed. After the stiffening of the slip it is immediately worked on a wheel. Most of the pottery is turned free-hand on ingeniously constructed wheels. In the turning down, solely a piece of band iron with sharpened edge is used. For a glaze which, as in Europe, is applied after biscuit-burning the pottery, a soft clay is used, to which is added as a flux the lixiviated and washed ash of Ficus Pyrifera, in the proportion of 100 parts of clay to 40, 60, and 80 parts of ash. According to the different degrees of heat in the different parts of the kiln, the pottery receives a more or less fusible glaze. For a greenish glaze a clay is used colored to an ochre yellow by iron, which is likewise mixed with wood ash. For the production of craquelé, the green pottery receives a coating of a calcareous mineral, over which the ordinary glaze is applied. The thicker this engobe, the closer will be the mesh of the crazing.

The burning is accomplished in kilns having the shape of bake ovens, built by tamping fire-clay over a wooden form without the use of brick. The kilns are built in a row of twenty up a hill slope. The fire enters from one kiln into the other, so that the entire row is burnt in succession. The lower kilns are very small, only about two meters in diameter; going up they become larger up to eight meters. Only the most valuable ware is burnt in saggars of porcelain body, which must always be destroyed; the ordinary products are burnt in the open fire, supported by benches of fire-clay which are built in the kiln on clay pillars up to a man's height. Every piece in the kiln rests on a porcelain tile. In burning, care is taken that in the beginning white heat, when the porcelain commences to vitrify, the kiln is filled with flame.

I. BODY AND GLAZE

In the following section, I shall give the composition of the Japanese bodies as shown by analysis, as well as the composition of several European bodies which will serve for comparison with the Japanese.

From the table two conclusions can be deduced.

1. That in the European bodies the content of silica in the average is lower, but the alumina content higher than in the Japanese porcelain bodies.

The European porcelain bodies have:

	Maximum.	Minimum.
Silica - - -	66.78	52.94
Alumina - - -	28.91	22.70

Japanese porcelain bodies have:

	Maximum.	Minimum.
Silica - - -	74.53	71.31
Alumina - - -	19.94	16.09

Here the Japanese body IV has not been taken into consideration, since it was brought for examination only in the biscuit state. It is probable that it is identical with body I.

2. That the clayey bonding material has a different composition from that which we know to be present in the European porcelains. The composition of the clay substance of the European porcelains corresponds, as I have stated before, to the formula $Al_2O_3.2SiO_2 + 2H_2O$ which requires

	Per cent.
Silica - - - - -	46.33
Alumina - - - - - -	39.77
Water - - - - -	13.90

The clay substance of the Japanese porcelains shows a material deviation from this, which becomes evident at once through the high content of alkalies and the low content of water. The alkali content in the clay substance of the European porcelain amounts on the average to 1.75 per cent, but in the Japanese from 5.76 to 7.12 per cent. This difference might indicate that the Japanese porcelain bodies contain as a flux, a variety of feldspar or another mineral containing potash, which, like the clay substance, is dissolved by sulphuric acid, or that the composition of the clay substance approaches that modification which forms the bonding material in strongly plastic clays. Perhaps, both causes enter into the explanation of the different compositions.

Now assuming, in order to be able to compare the bodies with each other, that in the Japanese as in the European there actually belong only 1.75 per cent of alkali to the clay substance, and calculating the excess of alkali into the feldspar, the following composition is deduced for the Japanese bodies:

	1.	2.	3.
Clay substance	24.56	30.90	34.79
Feldspar	34.53	19.66	23.69
Quartz	40.91	45.36	41.52

According to these figures the feldspar content in both the European and Japanese bodies fluctuates quite widely. A striking difference is shown in reference to the proportion between clay substance and quartz. In the European bodies the clay substance predominates always, and in the Japanese the quartz.

The following tabulation shows this distinctly:

European bodies.	Maximum.	Minimum.
Clay substance	66.37	42.05
Feldspar	36.84	17.05
Quartz	29.62	12.05
Japanese bodies	Maximum.	Minimum.
Clay substance	34.70	24.56
Feldspar	34.52	19.66
Quartz	45.35	40.91

From the relatively small quantity of plastic bonding substance found in the Japanese porcelains, the conclusion might be drawn that they are less plastic, and hence more difficult to work than the European bodies. However, on kneading, the body is remarkably plastic and dries to a hard, firm mass, while

	Séveres tableware body 1878.			Berlin tableware body 1877.			Limoges tableware body of J. Pouyat.			Carlsbad body of pottery at Dallwitz.		
	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance..	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.
Silica	52.94	22.75	45.17	63.07	38.09	45.49	64.28	44.70	45.47	66.78	41.48	48.59
Alumina	28.91	3.05	38.69	24.67	4.15	37.38	23.49	7.18	38.10	22.70	3.38	37.10
Ferric oxide	0.48	....	0.72	0.59	....	1.07	0.87	....	2.03	0.55	....	1.06
Lime	3.99	....	....	....	....	....	1.77	0.85	....	0.97	0.26	0.02
Magnesia	0.17	....	0.25	0.40	....	0.73	trace	....	....	trace	....	....
Potash	1.70	0.85	1.27	} 4.25	2.84	2.58	1.11	0.88	0.53	1.07	0.44	1.21
Soda	0.68	0.51	0.25				3.07	2.73	0.79	1.51	1.32	0.36
Water and organic matter	9.12	....	13.65	7.00	....	12.75	5.48	....	12.80	6.07	....	11.66
Carbonic acid	2.48	....	....	....	....	....	0.69	....	....	0.55	....	....
Totals	100.47	27.16	100.00	99.98	45.08	100.00	100.76	56.34	100.00	100.20	46.88	100.00

From these constituents the mineral components are calculated as follows :

Clay substance	66.37	54.92	42.05	51.87
Feldspar	15.11	21.56	36.84	17.26
Quartz	12.05	23.52	19.50	29.62
Calcium carbonate	6.47	....	1.61	1.25

	Japanese body I.			Japanese body II.			Japanese body III.			Japanese body IV. Biscuit of egg-shell porcelain.		
	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.	Total.	Insoluble in sulphuric acid.	Percentage composition of clay substance.
Silica - - - -	74.53	58.91	47.86	71.31	48.90	45.24	71.60	49.74	46.61	76.75	....	....
Alumina - - -	16.09	5.13	33.58	19.74	1.01	37.82	18.71	2.35	34.91	18.44	....	....
Ferric oxide - - -	1.03	....	3.16	0.73	....	1.47	1.19	....	2.54	1.17	....	....
Lime - - -	0.06	....	0.18	0.17	0.04	0.26	trace	....	....	0.02	....	....
Magnesia - - -	0.25	....	0.77	....	....	....	....	....	....	....	....	....
Potash - - -	4.37	3.67	5.78	4.04	0.54	7.06	4.16	1.46	5.76	4.23	....	....
Soda - - - -	1.19			0.10	0.07	0.06	0.18	0.09	0.19	0.17	....	....
Water and organic matter -	2.83	....	8.67	4.01	....	8.09	4.68	....	9.99	....	....	....
Carbonic acid - - -	....	....	....	....	....	....	....	....	....	....	....	....
Totals - - -	100.35	67.71	100.00	100.10	50.56	100.00	100.52	53.66	100.00	100.96	....	....

From these figures the following mineral components are calculated :

Clay substance - - -	32.29	45.36	46.34	......
Feldspar - - -	26.80	5.20	12.14	......
Quartz - - - -	40.91	45.36	41.52	......
Calcium carbonate - -	....	....	....	......

our bodies are usually soft and rub off easily. This indicates that the clayey bonding substance of the Japanese bodies approaches in its physical properties more or less the variety which is contained in the plastic, hard, bone-like clays, while in the European porcelain the real less plastic kaolin clay substance is introduced into the bodies.

It might now be expected that in using suitable white burning, very plastic clays, a body of equal plasticity as well as being also adapted for such various decorations as the Japanese body, could be produced.

First a body was prepared of the composition :

	Per cent.
Clay substance	32
Feldspar	27
Quartz	41

As raw materials there were used : Ebernhahn clay (containing 76.7 per cent of clay base, 23.3 per cent of quartz with traces of feldspar), Norwegian feldspar and ground Hohenbocka sand.

From this the body mixture

	Parts.
Ebernhahn clay	42
Feldspar	27
Sand	31

is calculated.

Of this very plastic body, small, thin-walled cups were made and burned with ground pegmatite (glaze of L. Sazerat at Limoges) as a glaze, at the lowest glost heat of the Berlin porcelain. It was found that the body was much too fusible ; the pieces were completely fused down, the glaze appearing strongly crazed. At the lower heat of the fire-brick kilns, however, the shape was retained, the body was highly transparent and the color was not as pure white as the Berlin porcelain, but had a grayish cast, which is also shown by most of the Japanese porcelain ; the glaze was crazed.

The first experiment showed that by not using any kaolin, but introducing a high content of quartz, satisfactory results could be obtained. The success of the experiment hinges only on the production of a more fusible glaze corresponding to the greater fusibility of the porcelain. For this purpose the following porcelain glazes were analyzed:

1. Old Berlin porcelain glaze (very likely from Dr. Elsner's time).
2. Pegmatite glaze from Limoges (from L. Sazerat).
3. Porcelain glaze from Limoges.
4. Japanese glaze from Arita, No. 1.
5. Japanese glaze from Arita, No. 2.
6. Chinese Seladon glaze.

These analyses gave the following results:

	1	2	3	4	5	6
	Berlin porcelain glaze.	Pegmatite glaze, L. Sazerat, Limoges.	Glaze from Limoges. P. Held & Co.	Japanese porcelain glaze No I.	Japanese porcelain glaze No. II.	Chinese Seladon glaze.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Silica	73.24	76.11	74.99	61.97	64.96	64.88
						1.39 titanic acid
Alumina	13.97	14.61	14.80	12.92	12.74	14.33
Ferric oxide	0.31	0.66	0.37	0.39	0.80	1.39 ferrous oxide
Lime	2.57	1.44	1.09	9.59	8.78	10.09
Magnesia	0.51	0.42	0.36	trace	trace	1.55
Potash	4.81	2.99	4.31	4.17	1.95	5.61
Soda	1.71	3.03	3.49	1.12	2.30	0.81
Phosphoric acid				0.30	0.16	
Loss on ignition	3.83	1.23	0.65	9.91	9.19	
	100.95	100.59	100.06	100.37	100.88	——

On calculating from these analyses the ratio of the fluxes RO (lime, magnesia, soda, potash), to the more infusible ingredients, R_2O_3 (alumina and ferric oxide), and silica, the following proportions are obtained:

	$RO : R_2O_3 : SiO_2$	$R_2O_3 : SiO_2$
Berlin glaze	1 : 1.00 : 8.91	1 : 8.91
Limoges glaze (Sazerat)	1 : 1.24 : 10.84	1 : 8.74
Limoges glaze (Held & Co.)	1 : 1.12 : 9.58	1 : 8.55
Japanese glaze I	1 : 0.55 : 4.42	1 : 8.04
Japanese glaze II	1 : 0.59 : 5.04	1 : 8.54
Chinese Seladon glaze	1 : 0.52 : 3.82	1 : 7.35

From this it is seen that while the ratio of silica to the sesquioxide is nearly the same in all porcelain glazes, the amount of the fluxes proper (lime, magnesia, soda, potash) in the Japanese and the Chinese glazes is about double that of the French and Berlin glazes. From this it follows that the Japanese and Chinese glazes must be much more fusible than the others.

According to the analysis of the Japanese glaze I, a porcelain glaze was prepared from:

	Per cent.
Marble	15.7
Feldspar	31.3
Washed Zettlitz kaolin	17.6
Ground sand	35.4

The glaze melted on the porcelain body mentioned before at a much lower heat than that to which we are accustomed. The temperature was such that tetrahedra of feldspar were rounded at the edges, but did not fuse down to a drop, hence had not yet reached the melting-point of feldspar.

Samples of transparent enamel also obtained from Japan, about whose composition I shall later make a communication, adhered perfectly to the glazed surfaces while they cracked off from our European porcelain. Thus the task of producing a porcelain on which the enamel painting will hold, was solved.

It further seemed to be of interest to determine whether in the selection of the raw materials, especially of the clays, accidental conditions could assist in producing equal expansion of body and glaze, as well as of the enamels, or whether any clays, if sufficiently free from iron, refractory and freed from impurities are suited for the production of porcelain of the Japanese type. For this purpose body trials of other clays were made maintaining a similar composition. The composition selected was:

	Per cent.
Clay substance	25
Feldspar	30
Quartz	45
	100

The calculation of the mixtures was based on the following mineralogical compositions of the clay materials:

	Clay substance.	Feldspar.	Quartz.
Plastic clay from Gundlach Bros., Grosalmerode	86.91	2.15	10.94
Lean clay from Gundlach Bros., Grosalmerode	44.04	2.53	53.43
Clay from Ebernhahn near Coblenz (stoneware clay)	76.75	1.03	22.22
Clay from J. Hersel, Ullersdorf	69.91	trace	30.09
Clay from Loethain	62.24	trace	37.76
Kaolin from Zettlitz	96.55	1.15	2.30
Kaolin from Sennewitz	63.77	0.75	35.50
Saggar clay from Salzmuende	49.33	0.79	49.86

Feldspar as Norwegian spar and quartz as Hohenbocka sand were considered as chemically pure substances. The slight content of feldspar in the clays was not considered in the calculation. The numbers of the batch weights are always rounded to whole or half per cents.

The bodies all behave uniformly in the fire in regard to maturing temperature and stability of the glaze, and the enamels applied on it; they differ from each other only by the color and the degree of plasticity. On carefully avoiding reducing smoky conditions they all assume a distinctly yellow color which is the more pronounced, the higher the clay used is in iron, and thus the darker it burns in itself. With the deeper yellow color the transparency also diminishes. With periodically reducing conditions of the fire in the glost-burn all the materials assume a white color, which is the purest in bodies 2, 6, and 7, and in the others tinges somewhat into bluish or grayish. This tinge is

Number of porcelain body	Composition of body.	Per cent.	Remarks.
1	Plastic clay from Grosalmerode	28.8	Ivory color in clear fire with a grayish tinge; white in smoky fire, somewhat grayish; shows good translucency.
	Ground feldspar	30.0	
	Ground sand	42.0	
		100.0	
2	Plastic clay from Grosalmerode	14.0	As before, somewhat lighter in color; good translucency.
	Zettlitz kaolin	13.0	
	Ground feldspar	30.0	
	Ground sand	43.0	
		100.0	
3	Clay from Ebernhahn	16.5	As No. 2.
	Zettlitz kaolin	13.0	
	Feldspar	30.0	
	Sand	41.5	
		100.0	
4	Clay from Ebernhahn	16.5	As No. 2.
	Sennewitz kaolin	19.0	
	Feldspar	30.0	
	Quartz	34.5	
		100.0	
5	Lean clay from Grosalmerode	28.5	Deeper yellowish and less translucent.
	Zettlitz kaolin	13.0	
	Feldspar	30.0	
	Quartz	28.5	
		100.0	
6	Ullersdorf clay	36.0	Of a good white color in smoky fire; ivory color in clear fire; very translucent; hard to turn, owing to slight plasticity.
	Feldspar	30.0	
	Quartz	34.0	
		100.0	
7	Loethain stoneware clay	40.0	As No. 6 as to color and translucency; quite plastic.
	Feldspar	30.0	
	Quartz	30.0	
		100.0	
8	Salzmuende saggar clay	51.0	Somewhat deeper yellowish than No. 7; not quite as translucent; good plasticity.
	Feldspar	30.0	
	Quartz	19.0	
		100.0	

the more pronounced the deeper yellow the color is in the clear fire. The transparency in all cases is greater than that of the Berlin porcelain.

From this it follows that taking into consideration the quartz and feldspar content naturally occurring in the clay and maintaining a high content of quartz, porcelains of ivory-yellow or white color can be produced from all white or light yellow burning fire-clays.

The addition of the plastic clays, usually not employed, to the porcelain bodies was made for the reason that the latter, owing to their high content of the non-plastic constituents, would become so short and hard to work, with pure kaolin as the plastic component, that difficulty would be experienced in turning the ware on the wheel. This was actually the case, and in all experiments involving the decoration of the porcelain subsequently described such bodies were used, which beside the kaolin possessed at least a certain portion of plastic clay.

But I believe that bodies so high in non-plastic matter as the Japanese mixtures, could be employed when containing kaolin alone, without the addition of plastic clay, and in this connection I want to call attention to the remarkable molecular change which is brought about in the bodies in consequence of a change in the reaction of the water used in preparing the bodies. If a body slip which is made up in water is allowed to settle and the clear water is drawn off, a paste is obtained so stiff that a glass rod can be inserted in it without falling over. If now the water still remaining is made weakly alkaline by an addition of a few drops of caustic soda, sodium carbonate, or sodium silicate, the body experiences a remarkable change. It becomes considerably thinner, and a large part of the non-plastic matter contained in it is precipitated. This portion quickly settles to the bottom, forming a compact mass ; the thin clay slip on top requires an extraordinary long time to clear up. If, however, a few drops of acetic or hydrochloric acid are added to the body so that its water reacts acid, the body stiffens so decidedly that the vessel can be upset without fear of spilling any slip. After drying to a stiff mass the body, made acid, has become more plastic to a remarkable extent, while the one made alkaline has lost its plasticity almost entirely. I believe that this change must be traced back to the property of the body of being easier to work after storing and rotting for some time than when it is freshly prepared. The change in the properties of the body cannot, I believe, be explained by assuming a continued weathering of the feldspar in this rotting. Now the water, which is present in freshly prepared bodies, always reacts weakly alkaline, which is explained by the fact that alumina absorbs alkaline salts which are produced in the weathering of the feldspar. On allowing ordinary well water to stand for a long time the organic matter contained in it will pass into fermentation and form acid compounds, which tend to make the body more plastic. If it is desired to avoid the long storing of the body one need only make it somewhat acid by the addition of an acid, which produces the same result, in fact, makes the body more plastic than storage. Thus it is possible to produce sufficiently plastic bodies by imparting to the prepared mass an acid reaction, on adding a slight quantity of any acid, without an addition of a plastic clay, rendering them workable on the wheel or suitable for casting.

The bodies which I have used for decorated ware always contain plastic clays, as already stated above. These possess the character of the Japanese bodies examined, that is, they always were very high in quartz according to the composition:

	Per cent.
Clay substance	25
Feldspar	30
Quartz	45

They were composed of:

	Per cent.
Loethain clay (from H. Ruehle)	31.0
Feldspar	30.0
Ground sand from Hohenbocka	39.0
or Loethain clay	15.5
Sennewitz kaolin	19.0
Feldspar	30.0
Ground sand from Hohenbocka	35.5
or Loethain clay	15.5
Zettlitz kaolin	13.0
Feldspar	30.0
Ground sand from Hohenbocka	41.5

The clays were composed of:

		Per cent.
Loethain clay	Clay substance	81.0
	Sand	19.0
Sennewitz kaolin	Clay substance	65.0
	Sand	35.0
Zettlitz kaolin	Clay substance	97.0
	Sand	3.0

The composition of the bodies was slightly changed only when fluctuations in composition were detected in the examination of later shipments of materials. But from every clay free from lime, making allowance for the quartz and feldspar contained in it, a uniform body can be calculated, provided the material proves sufficiently free from iron and contains no constituents which cause blotches and spots. As porcelain glaze, one of the composition

$$\left.\begin{matrix} 0.3K_2O \\ 0.7CaO \end{matrix}\right\} 0.5Al_2O_3,\ 4SiO_2$$

was used, although in the beginning of the experiments other compositions very similar to this were applied; this glaze proved to be by far the most easily fusible one of the possible porcelain glazes, free from lead and boracic acid.[1] It was composed of feldspar, ground sand, Zettlitz or Sennewitz kaolin and ground marble, in the proportions:

	Parts.
Marble	17.7
Feldspar	42.1
Zettlitz kaolin	13.0
Ground sand	27.2

or

Marble	17.7
Feldspar	42.1
Sennewitz kaolin	19.2
Ground sand	21.0

A porcelain thus compounded has tempting properties; it is very translucent, has only a slight shrinkage owing to the large quantity of non-plastic materials, a pleasant white or ivory yellow color, and a much lower finishing temperature, about 1300° C. or cone 8 to 10.

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[1] See chapter on "Pyrometers and the Measurements of High Temperatures. Standard Cones," p. 224.

In spite of this I do not recommend it for the production of all kinds of porcelain. The much lower temperature which it requires and which causes it to be less expensive cannot alone decide its use. It, like all translucent porcelains of Asia, is more sensitive to a quick change in temperature and to a sharp knock than our ordinary porcelain, richer in alumina, and this peculiarity alone would keep it from general application.

Hence, for ordinary household and kitchen ware, it is not a suitable material ; on the other hand it is much to be preferred to the ordinary porcelain on account of its decorative possibilities for artistic ware, and it will certainly find extensive use in this department. Hitherto, such porcelain has been produced only by the Royal Porcelain Factory for ornamental ware and has been brought on the market under the name of "Seger Porcelain."

Although it has been possible in the past to produce a number of colored glazes on porcelain, the body reproducing the Japanese porcelain offered this possibility in a higher degree and permitted the production of a very rich color scale. This was not only made possible by the much lower temperature to which it is exposed and which does not permit the destruction and vaporization of colors as readily as is the case with the ordinary hard porcelain, but also by the possibility of managing the burning with the less active oxidizing fire-gases. We shall learn to value the latter feature when we have shown what changes must take place in the glazes when we expose them to the fire. Let us first consider the plain white porcelain glaze, consisting of silica alumina, lime and alkalies.

In studying the effects of the fire-gases, which we suppose to have been produced by means of wood, thus containing nothing but the products of combustion of the pure carbon and hydrogen, we cannot see what influence the latter could exert on the glaze. The glaze ingredients in question cannot be changed or vaporized either by oxidizing or reducing fire-gases ; they must melt as soon as the required temperature is reached, whatever the condition of the fire-gases may be, whether oxidizing or reducing, without a change in the composition. Neither excess of oxygen can produce a change in the glaze because there are no constituents contained in it which may be oxidized, nor the reducing gases, carbon monoxide and hydrocarbons, because there is nothing to be reduced, nor the indifferent gases, carbon dioxide and steam. Only the presence of sulphur in fire-gases, which of course is out of question in firing with wood, but which is always found in fossil fuel, peat, lignite, coal and anthracite, may cause a change in the composition of the glaze. When the sulphur of the fuel burns to sulphurous acid and the fire-gases contain excess of oxygen, they might unite to form sulphuric acid; the latter combines with the potash or lime of the glaze, and this the more readily the lower the kiln temperature, for, in the first place, the glazes are attacked better in the loose, unfused condition, and again the lime reacts more energetically because it has not yet entered into combination with silicic acid. This content of sulphuric acid, entering into the glaze at a low temperature and under oxidizing conditions, is again removed, as soon as the fire-gases change from the oxidizing to the reducing condition. If this expulsion of sulphuric acid is accomplished while the glaze shows as yet no indication of melting, and consists of small solid particles adjoining each other, it will be effected without causing any damage, but if a union of the single particles has taken place by incipient fusion, some portions of the gases evolved are easily enclosed in the glaze. Thus either blistering, eruptions of the glaze, or at least an egg-shell-like surface, is produced. But if the glaze is already vitrified when the reducing gases approach it, they will exert a less powerful influence upon the surface, on account of the small area exposed; at least this influence will be limited to the surface layers. The same will be the case, if beside the sulphuric acid present in the glaze or introduced by the fire-gases, there are also present oxides of the heavy metals, which are affected by reducing gases. Those which might serve as glaze colors and which are easily reduced, are the oxides of iron, manganese, copper and uranium, while cobaltous oxide, the lower oxide of nickel, chromium oxide and the noble metals are changed only in so far as they contain quantities of the former.

I made the remarkable observation in my various burns, carried out under analytical supervision, and which solely consisted of pottery carrying colored glazes, that when the fire-gases were strongly reducing, that is, when they contained about 4 to 8 per cent of carbon monoxide, the surface of the glazes was always bright and smooth, but that it showed the changes in color which are always produced by the reducing gases in a decided manner. When, however, the reducing effect of the fire-gases was only slight and they contained only 0.5 to 1 per cent of carbon monoxide, the change in color thus caused was always slighter or scarcely to be observed, but the surface of the pottery appeared dull and showed quite decidedly the familiar defect of "egg-shell surface" and also blisters. This fault appeared especially when during the temperature at which the glaze commences to vitrify a slightly reducing kiln-atmosphere prevailed. My explanation of the phenomena is that in a strongly reducing atmosphere the process of reduction is quickly completed and a large quantity of soot is always deposited from the fire-gases; the soot enters deeply into the glaze-layer and the body, and surrounds the smallest particles, retards complete fusion and allows the gases evolved in the glaze to escape freely without bloating the glass-mass itself. But if the reducing effect is weak the evolution of gases from the glaze, be they sulphurous acid originating from the decomposition of sulphates, or carbon dioxide, which arises from the burning of the carbon monoxide to carbon dioxide taking up oxygen from the reducing heavy metallic oxides, will be continued for a longer period and the reduction is often incomplete; but since there is no obstacle opposed to the flowing together of the separate glaze particles by deposited carbon, the gases developed are readily enclosed by the fusing glass. But when once an inclusion of small gas bubbles in the glaze has taken place, these can escape only when the glaze has reached the required condition of perfect fluidity, a condition which in many glazes is not desired, because the glazes would run off strongly, or would flow into each other at too high a heat.

There are two things to be feared in colored glazes: first, the evolution of sulphurous acid from the glaze, which may be contained in it either naturally as an impurity of its constituents in the shape of sulphates, or by absorption from the fire-gases, and second, the reducing action of the kiln gases upon the metallic oxides added for the purpose of coloring the glazes.

If it is difficult in the porcelain industry to fuse a good white glaze from an otherwise good glaze composition with a fuel containing sulphur, like coal, and a certain amount of practical experience on the part of the burners is required, the difficulties are increased still more in the burning of colored glazes. Here not only the surface gloss disappears on faulty burning, but also the color is changed, thus causing harm in two ways.

I have so far expressed myself about these questions really not belonging to my fixed theme, because I want to warn interested parties from endeavoring to burn colored glazes with coal. The difficulties connected with it are so great on account of the ever present sulphur content, that it is better to desist from the attempt, since if a little care is exercised one works cheaper with wood as fuel. But even with the use of wood not every furnace can be employed. It is best to work with inclined grate or step grate furnaces, with which the process of combustion can be regulated in quite a positive way, regulation being a necessary condition in the melting of colored glazes, especially of colored porcelain glazes.

I have always worked most advantageously by burning with a strongly reducing fire up to gold-melting heat, or at most up to cone No. 1 at the fire inlet. At this temperature the glaze is not yet vitrified, and it can again be completely oxidized by the time fusion sets in, so that no effect of the reduction can be detected after the burn. This reduction removes any sulphates from the glaze and the body. From here on, however, the burning must be oxidizing, and this is accomplished with an excess of oxygen in the fire-gases of from 4 to 6 per cent; that is, with an air excess of from about one-fifth to one-third of the amount theoretically required and careful attention must be paid to prevent the fire-gases from becoming reducing at times. When at last the glaze has entered the state of fusion, which takes place at the melting-point of cone No. 4,[1] it is necessary to avoid a smoky flame most carefully. When the burning was carried on in this manner the glazes were always clear and bright, but if once a mistake was made in firing during the stage of fusing the glaze, the results were less pleasing, the colors especially were easily injured by any reduction, or occasionally a rough, egg-shell-like surface appeared.

Now in regard to the composition of the colored glazes used by me, I have taken as a principle never to be disregarded that the composition of all the glazes must be uniform in order to render the many mixtures used as uniformly fusible as possible. Thus when the coloring metallic oxide is a monoxide as cobaltous oxide, nickelous oxide, or copper oxide, a quantity of calcium carbonate equivalent to the quantity of coloring oxide added is taken from the white glaze, but when the coloring oxides are sesquioxides they are made to replace some of the alumina, the addition of kaolin to the glaze being decreased and that of flint increased. By means of the coloring oxides, a number of fundamental glazes were compounded which contained such a quantity of the metallic oxide that a crystalline segregation could not possibly appear on cooling, a phenomenon which readily occurs with very dark glazes. These fundamental glazes were then mixed with each other in the proportion of 1 : 1, or 1 : 3, and thus a series of about 125 different shades was produced, which number can still be increased. The colored glazes recently used had a composition invariably corresponding to that of cone No. 4, as being that of the white porcelain glaze.

The ingredients, after the proper purification of the oxides by igniting at a low heat and washing, are first weighed, then the oxides together with a smaller quantity of the other glaze ingredients are very finely ground in a small ball-mill, and finally the other ingredients are added and well mixed with the coloring oxides by grinding for several hours. Finally, the glazes

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[1]

Marble	17.7
Feldspar	42.1
Quartz sand	27.2
Zettlitz kaolin	13.0

thus compounded were freed from the sulphates always contained by them, by repeated washing with pure water, free from sulphuric acid, rain water being best—a procedure which is very important for the production of good bright glazes. The mixtures of the fundamental glazes were then made up to the same consistency as nearly as possible by blending according to volume.

The compositions of the glazes were as follows:

1. Dark blue glaze with a content of 3 per cent of the black cobalt oxide of commerce:

	Per cent.
Black cobalt oxide	3.0
Marble	14.1
Feldspar	42.1
Quartz sand	27.2
Zettlitz kaolin	13.0

For light blue this was compounded in the proportion of 1 part of dark blue glaze with five parts of white so that the content of cobalt oxide was thus lowered to 0.5 per cent.

2. Dark Seladon glaze with a content of 2 per cent of copper oxide:

	Per cent.
Copper oxide	2.0
Marble	15.2
Feldspar	42.1
Quartz sand	27.2
Zettlitz sand	13.0

For light Seladon, a mixture of this glaze with 3 parts of white glaze was used, so that a glaze with 0.5 per cent of copper oxide was produced.

3. Dark brown glaze with a content of 2 per cent of nickel oxide:

	Per cent.
Nickel oxide	2.0
Marble	15.3
Feldspar	42.1
Quartz sand	27.2
Zettlitz kaolin	13.0

4. Yellowish brown glaze with a content of 5 per cent of iron oxide:

	Per cent.
Iron oxide	5.0
Marble	17.7
Feldspar	42.1
Quartz sand	30.9
Zettlitz kaolin	5.0

5. Violet-brown glaze with a content of 5 per cent of manganous manganic oxide:

	Per cent.
Manganous manganic oxide	5.0
Marble	17.7
Feldspar	42.1
Quartz sand	31.2
Zettlitz kaolin	4.6

6. Green glaze with a content of 1 per cent of chromium oxide:

	Per cent.
Chromium oxide	1.0
Marble	17.7
Feldspar	42.1
Quartz sand	28.0
Zettlitz kaolin	11.3

7. Yellow glaze with a content of 5 per cent of uranium oxide:

	Per cent.
Uranium oxide	5.0
Marble	17.7
Feldspar	42.1
Quartz sand	29.3
Zettlitz kaolin	8.5

8. Dark red glaze:

	Per cent.
Pink I	10
White porcelain glaze	90

9. Rose color:

	Per cent.
Pink II	6
White porcelain glaze	94

The pink color consists mainly of chromate of tin and is compounded from:

Pink I.

	Per cent.
Ignited tin oxide	50
Marble	25
Quartz	18
Potassium bichromate	3
Borax	4

Pink II.

	Per cent.
Ignited tin oxide	50
Marble	36
Potassium bichromate	4

The colored porcelain glazes which need not be fritted are now applied to the ware in the ordinary manner by dipping the biscuit-burned vessels into the glaze slip. If the ware to be glazed is very large, so that for dipping it large quantities of glaze are required, the glaze can be applied, if the vessels are plain in shape, possessing a smooth surface without relief decorations or other prominent parts, like handles, by means of spraying with a vaporizer. In this case the vessel is put on a wheel and rotated slowly, while by means of an ordinary sprayer as used for spraying plants with water, fed with a strong stream of air from a small smith's bellows, a fine spray of glaze is applied to the surface. This has the advantage that it is not necessary to keep large quantities of glaze on hand, but that it is possible to glaze with smaller quantities. Of course the glaze must be applied in uniform thickness and a certain skill on the part of the glazer is required in the operation.

In this manner a rich decoration of the porcelain is possible, not only by covering the ware with different colored glazes, but also by inlaying different colored glazes very tasteful decorations can be produced. For this purpose the vessel to be decorated is first covered with a ground-glaze; the design is then traced on it and the ground scratched off by means of a steel pencil and knife following the lines of the traced design. After this has been done another colored glaze is applied by means of a brush on the bare places, until the depressions caused by removing the ground are again completely filled; the surface is then scraped evenly with a knife blade and the piece taken to the glost-burn. After the glost-burn of the pottery its decorations may be bordered with gold, or enamel can be burned on to the glaze in drops, in the muffle.

This manner of decoration which has been practiced by Dr. Sarnow of the Royal Porcelain Factory and also by Buenzli on the Bohemian porcelain years ago, is a very agreeable one, but permits on the more fusible Japanese porcelain a much richer color decoration than on the ordinary hard porcelain. Another decoration of the colored porcelain is the so-called craquelé. But this is quite a different technique from that usually termed craquelé on Chinese and Japanese porcelains. This decoration is formed by two differently colored glazes applied in two layers, in which the upper coating, which of course must be fused in a second burn, undergoes cracking through which can be seen the color of the lower glaze. Although this decoration often succeeds by simply superimposing the above-mentioned colored glazes, yet this is not always safe, and especially when the upper layer of glaze is thin, it might melt without showing the intended crazing. Now in order to produce the cracks on drying, or in the first stage of burning without fail, we may proceed in such a way that in place of the clay entering into the glaze a mixture of aluminum hydrate and silica is introduced. The commercial aluminum hydrate has on the average a content of 33 per cent of alumina; thus one would have to replace each 5 per cent of Zettlitz kaolin by 6 per cent of aluminum hydrate and 2.33 per cent of quartz, in order to retain the desired composition of the glaze. The aluminum hydrate shrinks considerably on slight ignition and thus causes a cracking of the glaze before fusion, the color of the lower glaze appearing through the cracks.

THE RED AND FLAMED CUPROUS OXIDE GLAZES

Of special interest is the peculiar red glaze which is found on old Chinese porcelain and which for this reason is called Chinese-red, also Sang de beouf or ox blood.[1] On the character of the color of this glaze Messrs. Lauth and Dutailly published an extensive treatise in which they describe the method used by them in its production. In this treatise these gentlemen, formerly active in the factory at Sévres, proved that this color can be imparted only to a body which requires a lower finishing temperature than that which is necessary for European porcelain. The porcelain used by them is like the Chinese, one containing very much silica, and which hence vitrifies easily, a body which is now made quite extensively at Sévres as "pâte nouvelle de Sévres," and whose glost temperature is stated as being 1300° C. They give the mixtures of two glazes of this kind and say that the red color of the glaze is produced in presence of tin oxide by a violent process of reduction, to which the ware is exposed in burning. The copper oxide is reduced to metallic copper, this being dissolved in the glaze and imparting to it on slow cooling a copper-red color, while on more rapid cooling a colorless glaze is produced, which, however, becomes red on slow gradual heating. The mixtures stated as being the best glazes are according to the writers mentioned above:

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[1] This glaze was first produced on a larger commercial scale in Europe by Seger. See "Das Porzellan-Scharffeuer Roth der Europaïschen Fabrikation." Thonind. Ztg., 1883, No. 7.

	I. Parts.	II. Parts.
Pegmatite	40	40
Sand	40	44
Chalk	18	12
Calcined borax	12	—
Soda	—	24.5
Oxide of copper	6	6
Oxide of tin	6	3

Whether a part of the ingredients is previously melted to a frit they do not say, but this is very probable. The ingredients of a glaze, soluble in water, here soda and borax, are as a rule fritted with other compounds in order to render them insoluble. Since I have also worked a great deal on the production of such a red glaze and have made such glazed porcelain bodies on a larger and commercial scale at a time before Messrs. Lauth and Dutailly appeared with their invention, I believe to be likewise in position to express some opinion concerning this extremely difficult process. I shall not give in detail the many experiments in this direction, which comprise 300 to 400 glazes of different composition. This would involve too much and would not benefit the manufacturer; but I will give my theoretical objections to the reasoning of Messrs. Lauth and Dutailly, and shall support these by proofs.

I cannot agree at all with the opinion of these investigators regarding the production of the red color by a segregation of metallic copper from the glaze, that is, by a simple and strongly reducing firing condition. On the contrary, alternately reducing and oxidizing conditions of the fire-gases are required in order to produce it, and the difficulties of the manufacture lie less in the composition of the glaze itself (although this is also of importance) than in the proper constitution of the fire-gases. It was shown in the production of the red color that in using one and the same glaze, not only the shade of color in the same burn is subjected to extraordinary fluctuations, so that it runs through all shades from black through brown to sealing-wax-red and light bluish green, but also that some pieces are colored differently on one side than on the other, according to the intensity of the draft through the piles of saggars; some burns may produce in the same glaze a more or less beautiful color than others, and again some burns may be totally spoiled and not produce any red color at all, everything appearing gray or black.

Now let us see, how cuprous glazes behave in a reducing fire or fusing in a reducing gas, and let us first take such white-ware glazes free from lead, which beside copper oxide contain no other metallic oxide that could be reduced. For example a glaze having the stoichiometric composition

$$0.5Na_2O,\ 0.5CaO,\ 2.5SiO_2,\ 0.5B_2O_3,$$

a glaze which melts smooth at about the melting-point of silver, and is made by fritting together

	Parts.
Pure sodium carbonate	26.5
Marble	25.0
Ground quartz	75.0
Hydrous boric acid	31.0

and which, after the melting, is ground together with 1 per cent of copper oxide. This mixture is put into a small porcelain crucible which is placed in a platinum crucible; the crucible is provided with a perforated porcelain lid and through the opening a thin porcelain tube is introduced, as in the Rose reduction crucibles of the laboratories. The mixture is not put into the platinum crucible directly in order to prevent the platinum from alloying with the copper of the mixture.

If we heat the glaze mixture in a stream of hydrogen or carbon monoxide introduced through the porcelain tube, to dark red heat, that is, to 400° or, at most, 500° C., the copper oxide is reduced and the glaze does not melt but is only fritted together. It has a red color caused by the copper segregated out.

If we now apply a higher heat, maintaining a current of hydrogen or carbon monoxide, about to silver-melting heat—the highest temperature obtained by a Bunsen burner—the metallic copper disappears, the copper flakes dissolve in the melting glaze, the red color vanishes and the completely molten glaze has now received a greenish gray color. If we coarsely powder this gray mass and again melt it together with the same white glaze, to which a trifle of some oxidizing agent is added, say 1 per cent of ferric oxide, stannic oxide, or a sulphate, like gypsum, but this time in a stream of air, in the crucible of the test kiln mentioned below, there is obtained a glass of a beautiful red color.

We must attribute this reaction to the fact that by the oxidizing agents which are contained in the glaze free from copper, the black metallic copper enclosed in the copper glaze is changed to cuprous silicate and this imparts to the glass a red color, for the ingredients react as follows:

$$2Cu + Fe_2O_3 = Cu_2O + 2FeO$$
$$2Cu + SnO_2 = Cu_2O + SnO$$
$$2Cu + SO_3 = Cu_2O + SO_2.$$

The last reaction is remarkable, owing to the fact that a lively evolution of gas takes place in the fusion. If the glass is allowed to cool, before it has become entirely clear, thus still retaining some bubbles, the presence of sulphurous acid can be proved by the smell on opening the bubbles.

If we now produce a glaze of a higher melting-point, mixing the whiteware glaze given with the white porcelain glaze mentioned above,

$$\left.\begin{matrix}0.3K_2O\\0.7CaO\end{matrix}\right\}0.5Al_2O_3\ 4SiO_2,$$

we obtain a glaze which at silver-melting heat only vitrifies but does not fuse. This glaze consists of 25 parts of the above copper whiteware glaze and 75 parts of the porcelain glaze. If we heat this likewise in a crucible, as was done before, at a silver-melting heat, introducing hydrogen gas or carbon monoxide, we again obtain a gray vitrified mass. On heating this in air, that is, in the open crucible, we observe that it assumes after a short time a reddish brown or red color, which, however, fades quickly, and whose place is taken by a light green color. We also observe in this connection that the strongest reducing action of the gases produces a black color, since it causes the reduction to metallic copper; that on admission of air this changes to a red color; that the copper is first changed to cuprous silicate; and that finally the green color of the cupric silicate appears.

If we heat the mixture more strongly over the blast-lamp, admitting a reducing gas, so that the glaze is fused, the mass thus formed remains gray in color and on heating in the air turns to a reddish color only on the surface, but in the interior it retains its gray color. On the vitrification of the glaze, further oxidation (and with it the red color) is excluded. A striking phenomenon is at the same time caused by the carbon deposited in the glaze. If the reduction is accomplished with illuminating gas instead of with hydrogen or carbon monoxide, a part of its carbon is deposited owing to the decomposition of the gas, which surrounds the glaze particles and thus prevents fusion. The glaze thus becomes apparently less fusible and retains its porous character even at the temperatures which lie above its melting-point. If glazes, reduced in this manner, are heated in the air, the carbon is burned out, but at the same time the copper segregated out is also oxidized to cuprous oxide and the glaze is now enabled to fuse. In this manner red glazes are always produced.

These experiments, performed in the crucible with pure reducing gases, were supplemented by others carried on in the test kiln, using a small test-kiln fired with gas (see page 224, Vol. I). This little furnace not only increases the rapidity of the experiments, but it also enables the experimenter to effect alternate reducing and oxidizing kiln conditions quickly and to control them by gas analysis. As trial pieces there are used small cups of biscuit-burned porcelain body, coated with a glaze, composed of 25 parts of whiteware glaze compounded with 1 per cent of copper oxide and 75 parts of porcelain glaze.

On heating these in the kiln, first in an oxidizing flame, until a glow is just visible, then in a strongly reducing flame, so that about 10 per cent of carbon monoxide is contained in the fire-gases, up to a temperature not exceeding gold-melting heat, we observe on pulling small glazed trials from the kiln with a pair of tongs that the glaze as well as the body possesses a dark color due to the deposition of carbon.

If we now allow the kiln to cool and do not close the damper so the air passes through the kiln for some time, we observe that the vitrified glaze coating has become beautifully red. When we fire under the same conditions, but higher, up to the temperature of cone No. 1, we obtain a fused glaze, gray in color, which, on properly melting the glaze in the oxidizing flame at about cone No. 1, changes more or less to reddish or brownish, but never assumes a fine red color. Repeating the same operation with another small porcelain cup, but with a lower content of carbon monoxide in the fire-gases, (2 to 3 per cent) the gray color appears still more intensely.

On firing a trial cup so that we first burn with a strongly reducing flame about up to silver-melting heat, and then burn alternately with a strongly reducing and oxidizing fire up to incipient fusion, about five minutes reducing and two minutes oxidizing, and after the fusion of the glaze finish the burning of the porcelain in the oxidizing flame, we obtain a fine red glaze. This red glaze is retained quite satisfactorily in the oxidizing fire after once it is fused and it can remain in the latter five to six hours without changing in color, though on the surface it may assume a pale green color due to oxidation. This nearly colorless extremely thin surface coating produced by oxidation gives to the pottery a special charm. Only when the glaze is very thin is it possible that the change in color might extend through the entire thickness of the glaze on remaining in the oxidizing atmosphere for a longer time, and such thinly glazed places, as well as the edges, and the relief decoration under the glaze assume a green color.

It is of special importance in the burning of red glazed porcelain that the fire be very sooty. Between the saggar rings which form the stack of saggars, I have always inserted on top and at the bottom of the ring, at the height of the ware, three small pieces of fire-clay tile of 1.5 to 2 cm. in thickness, so that the flame was freely admitted to the ware, and could always draw freely through the saggars. The deposition of carbon from the fire-gases has by no means the purpose of bringing about a very strong reducing effect, for the copper oxide is changed to copper even under weakly reducing conditions, but it should be the function of the carbon to retard the fusion of the glaze by depositing the soot in it. If now oxidizing conditions are suddenly brought about, avoiding neutral firing conditions as much as possible, the copper, during the burning out of the carbon from the glaze, again changes to cuprous oxide and is retained as such by the glaze which is fused soon after this change in firing. When the burning is accomplished without the deposition of soot on the surface of the ware, the red color will never develop, and the copper glaze always assumes a gray color, since then the closing of the pores of the glaze is not retarded and the metallic copper segregated out is deprived of the possibility of reoxidizing to cuprous oxide.

An experiment which I carried out endeavoring to burn a glaze, burning to a beautiful red with wood as fuel in a gas-fired kiln, using coke as a fuel, failed entirely; gray colored ware was always obtained.

Although on following the rules outlined above, a red color can be produced from every cuprous glaze in the crucible or in the small experimental furnace, the conditions in the large kiln are essentially different. It will not always be possible to produce a uniformly reducing atmosphere with a deposition of soot and it is especially difficult to produce strongly oxidizing conditions during a short time interval (one to two minutes); the red color in using any cuprous glaze will be obtained only rarely and in exceptional cases. But the production of the red color may be facilitated by imparting to the glaze a certain chemical and physical constitution.

The means of accomplishing this purpose consist first of a small addition of ferric or stannic oxide, in order to be independent of the oxygen of the atmospheric air alone for the translation of the copper to cuprous oxide. These metallic oxides are likewise changed to ferrous oxide and stannous oxide, but their re-formation to the higher oxides takes place quickly and thus they are enabled to oxidize the copper. Although an addition of these oxides by no means prevents the formation of the gray color, yet in their presence the red color appears much more readily. The tin or iron oxide is best melted in quantities of not more than 2 per cent, together with the copper oxide and the very fusible whiteware glaze which serves as a frit.

The quantity of copper oxide which is used is also of great importance for the beauty of the color. In my many experiments I have always used a content of copper of from 0.5 to 1 per cent and always obtained very good results. The more copper oxide there is in the glaze, the greater is the liability of some of the gray coloring metallic copper to remain in it and to change the sealing-wax-red color, which is produced by the pure cuprous oxide into a brownish color. With a content of 0.5 per cent of copper oxide to 100 parts of the finished porcelain glaze, the glaze where it is colored red is perfectly opaque. For transparent red glazes which on account of their transparency receive a deeper red color similar to gold-ruby, I have always used 0.10 to 0.15 per cent of copper oxide. With this content of copper oxide the glaze tends to produce green colors more readily, but at the same time the portions which have retained the red color are so much more beautiful. In regard to the quantity of the very fusible whiteware glaze (serving as a frit) necessary, this will always depend upon the temperature to which the body must be subjected in order to burn it to good porcelain. It may vary from 12 to 50 per cent of the finished glaze. The more fusible the glaze is to be the lower in silica it must be kept, the smaller may be its quantity and the more beautiful will be the red color developed; the less fusible it is, the more difficult is the production of the red and the more readily will the gray color of the ware be shown. As to the composition of the porcelain glaze being a component of the glaze, I have discussed it in the introduction; other porcelain glazes may very well be used, but care must be taken that the mixture remains as porous as possible; fused porcelain glazes cannot be used for this purpose as they are too dense.

Fluctuations in the composition of the white porcelain glaze are permissible according to the composition of the body and the temperature it requires; care must be taken, however, that it does not vitrify at too high a temperature, which is controlled by the addition of a very fusible whiteware glaze. Whatever the composition of the glaze for the Chinese-red or ox-blood color may be, a satisfactory result will never be obtained if the firing is not directed in a suitable manner.

After the ware is glazed, either by dipping or spraying, and has been set so that the smoke can reach it freely, at first, a fire as oxidizing as possible, is maintained. As soon as a dark red heat shows in the kiln, as much smoke as possible is to be produced and continued up to a temperature at which the glaze commences to vitrify. This is followed by short periods of oxidizing fire, kept up at short intervals, about one to two minutes for each quarter of an hour; between these, however, a strongly reducing kiln atmosphere must prevail. This mode of firing must be continued until the glaze has become dense and somewhat glossy. Thereupon the burning may proceed with oxidizing or reducing kiln conditions up to the close of the burn. This method of burning, however, will not be easy to carry out in ordinary coal furnaces, especially will it not be possible, as a rule, to produce the oxidizing fire-gases for so short a time without maintaining between time a longer or shorter period of neutral conditions. But in furnaces with inclined grates, fired with wood, one is enabled to produce such a change almost instantaneously by opening the air-passages beneath the charge of wood, and for this reason firing with wood will always remain the most satisfactory way of firing for the production of red copper glazes, if for no other reason than that it, more than any other, permits of a uniform and intense evolution of smoke.

For the porcelain compounded according to the composition of the Japanese, the following mixtures are suitable; that is, they have the proper fusibility and adhere without crazing. There is to be considered that the ones containing less cuprous oxide are always darker in color because transparent, and the ones high in copper appear lighter in color because they are opaque.

Dark red Chinese glaze:

	Parts.	
White porcelain glaze	75.00	
Copper oxide	0.15	Fritted in the reducing fire.
Tin oxide	1.00	
Ferric oxide	0.50	
Barium glaze $\left\{\begin{matrix}0.5Na_2O & 2.5SiO_2\\0.5BaO & 0.5B_2O_3\end{matrix}\right\}$	23.35	
	100.00	

Light red Chinese glaze:

	Parts.	
White porcelain glaze	70.0	
Zettlitz kaolin	5.0	
Copper oxide	0.5 to 1.0	Fritted in the reducing fire.
Tin oxide	2.0	
Barium glaze $\left\{\begin{matrix}0.5Na_2O & 2.5SiO_2\\0.5BaO & 0.5B_2O_3\end{matrix}\right\}$	22.0	

Blue iridescent Chinese glaze:

	Parts.	
White porcelain glaze	70	
Zettlitz kaolin	5	
Copper oxide	1	Fritted in the reducing fire.
Tin oxide	2	
Ferric oxide	1	
Barium glaze $\left\{\begin{matrix}0.5Na_2O & 2.5SiO_2\\0.5BaO & 0.5B_2O_3\end{matrix}\right\}$	21	

The blue iridescence of the glaze appears especially when the latter is again covered with a thin barium glaze and again burnt in the glost-burn.

There is yet to be stated, that fine red colors are obtained only when the difference between the melting-points of the two glazes used for this purpose is very great, and that they will be the finer and appear the more readily when the whiteware glaze is very fusible. It is produced the more difficultly the less fusible the glazes are, and it is impossible to obtain a pure red, when the red glaze is first fused completely and, again ground, is applied as a glaze. In this case it always is grayish black, with a brownish or reddish cast at best. This glaze differs considerably from the original Chinese glaze in that the latter is always very low in alumina. For this reason it devitrifies very easily, and the surface becomes dull owing to the crystalline compounds segregating out at a low temperature. Consequently the Chinese red ware can be decorated only with difficulty with gold and enamels or over-glaze colors. But with the glaze given this can very easily be done; care must, however, be taken, especially with the glazes low in copper oxide, that the vessels are cooled very slowly after the burning; it might happen that they loose their red color on quick cooling and come from the muffle-burn perfectly colorless.

Some interesting results have also been produced in the experiments which I have carried on in the direction of using the red glaze as a ground, and to inlay in it different colored glaze designs as I have described it in previous work. It sounds somewhat odd that it should be possible to burn a red ground-glaze on the same piece in the reducing fire, while the other colors, as I have previously stated, are produced satisfactorily only under oxidizing conditions. But it will be clear that it is possible to produce such work, if one remembers that the Chinese-red is produced at a comparatively low temperature and that a reducing kiln atmosphere does not injure the colors to be burned under oxidizing conditions, provided reduction prevails at a temperature at which they have not yet been rendered dense by incipient fusion. But the Chinese-red glazes given above and the previously mentioned colored glazes have the same melting-point, so that this can be accomplished without any trouble. For this reason ware thus decorated is first burned in a strongly reducing fire up to silver-melting heat, then in the oxidizing fire one to two minutes at intervals of fifteen minutes up to the melting-point of gold or not far above it. At gold-melting heat the red of the ground must be dense, and in this condition is capable of withstanding the oxidizing fire-gases without material injury of the color for several hours. The oxidizing burning is carried on very carefully in order to remove the effects of the preceding reduction, that is, to transform, in the glazes containing manganese, copper, iron, and uranium, the lower oxides again to the higher forms.

When the temperature has risen to the melting-point of the colored glazes, it will not be necessary to watch the oxidizing conditions of the kiln so carefully; on the contrary, it is advisable to reduce again during the last stage of the burn, because by this means the red glaze loses its egg-shell-like appearance, which it often shows, and becomes perfectly smooth. It is possible in this manner to burn even the very sensitive yellow glazes containing uranium as well as the pink glazes simultaneously with the Chinese-red.

This is always successful if the fire-gases are kept as strongly oxidizing as possible throughout up to its melting-point and care is taken that a reducing effect of the gases never occurs. Of course, this process can be considered only from the standpoint of an art-ware manufacturer, and for ordinary cheap ware this method, requiring such a difficult handling of the fire, cannot be considered. It can be put into practical operation only under certain conditions, which not every manufacturer is enabled to meet. In this connection it is especially necessary to know one's kiln accurately, so as to be able to handle it perfectly. Pottery of this character of Chinese or Japanese origin is not known to me.

RED UNDERGLAZE COLORS

On older Chinese vases there are sometimes noticed, beside the blue decoration, red underglaze colors apparently produced like the red glaze of the Chinese porcelain, with copper oxide.

Now the copper oxide is by no means a suitable underglaze color for it possesses the undesirable property of volatilizing strongly, and of spreading its coloring effect far around the decorated portions. This undesirable effect is noticeable only when the copper oxide is burned under oxidizing conditions; volatilization is not observed when reducing conditions prevail in the kiln. I have always noticed the spreading of the copper when it imparted to the glaze a green color, but never when the color was red.

It is suitable as an underglaze color when the porcelain glaze has a low fusing point; if the glaze is less fusible the composition of the fire-gases must approach close to the neutral condition in order to produce a higher temperature at all and then the color is, as I have shown, already in the burning of the red porcelain glaze with copper oxide generally not red, but gray or black. The copper oxide dissolved in a low fusing glaze also proved better suited for underglaze decoration than the pure copper oxide, and the colors in this way always appeared finer and surer. I have always obtained good results with the following mixture:

		Parts.	
Copper oxide		7.5	Fritted in the reducing fire.
Tin oxide		10.0	
Barium glaze	$\left\{\begin{matrix}0.5Na_2O & 2.5SiO_2\\ 0.5BaO & 0.5B_2O_3\end{matrix}\right\}$	82.5	
		100.00	

The production of the red decoration requires the same precautions as the production of the red glaze on porcelain. It is necessary here, too, that the cuprous silicate remain as such in the burning by excluding the atmospheric air by means of the covering of glaze. The reducing action of the fire-gases must not be stopped before the glaze covering the color has fused, thus protecting the copper compound from a reoxidation. If the white porcelain glaze is melted to a glass in the glost-burn and the ware after being decorated is glazed with this fused glaze, the latter will fuse somewhat earlier than if it is applied to the surface in the raw condition, and thus there is more assurance of obtaining the red. Furthermore, it is not absolutely necessary, although desirable, that the red color be applied to a body which has been well burnt. The body is often colored gray by the carbon deposited by the fire-gases which is always taken up into the pores of the porcelain during the strongly reducing fire, and hence the ware does not show the pure white color peculiar to porcelain. This is prevented if the body has been previously burned dense in an oxidizing burn. A simultaneous application of other colors is only permissible in a limited measure, as the fire-gases must always be kept strongly reducing in the burning of the red glaze; only the black, blue, and green colors resist reducing conditions. Other colors cannot be burned simultaneously with the red.

DECORATION WITH OTHER UNDERGLAZE COLORS

Like the application of colored glazes, underglaze decoration has never reached an extensive development on our hard European porcelains, because on account of the high temperature applied the color-scale must be a limited one. For this reason we see applied only the cobalt-blue in the Meissen onion pattern and similar decorations, and also the decoration with chrome oxide for green. But these colors when applied on porcelain are never subjected to variations in shade. However, underglaze decoration becomes more varied, as soon as it is possible to lower the glost-burn temperature from that of hard porcelain, about 1600° C. to about 1300° C., as is the case with the Japanese porcelain. In the latter the colors applied are much more protected from destruction and vaporization and it is now possible to apply, not the color-scale of the whiteware industry, but one embracing nearly the same colors.

In the use of metallic oxides for underglaze decoration on biscuit-burned porcelain the same things must be considered which I have discussed under the head of colored glazes. They must, like the glaze above it, be free from sulphates, because the latter cause them to foam at a higher temperature, and again, the composition of the fire-gases must, as a rule, be oxidizing in character, because the colors are materially altered by the reducing fire. Furthermore, the fire-gases must be as free from sulphur compounds as possible in order to prevent the metallic oxides, as well as the glaze itself, from taking up sulphuric acid from the fire-gases and thus causing the decorations to be finely blistered and egg-shell-like. For these reasons it is advisable to burn always with wood which applies to colored glazes as well as to underglaze decoration. Manufacturers of porcelain, who burn underglaze cobalt-blue in their kilns fired with coal, know very well how often the desired blue is not obtained, but boils up, although blue is a color capable of resisting reducing gases. With other colors such mishaps occur much oftener, hence it is best, when using underglaze colors, to burn with wood.

As with colored glazes a reducing fire does not hurt at all, and modifies the colors, if at a time, sufficiently long enough before the fusion of the colors or of the glaze, an oxidizing fire is maintained. The glaze of the Japanese porcelain melts, as I have already stated, at cone No. 4, but vitrifies to some extent, somewhat sooner, at cone No. 2 or No. 3. For this reason a smoky fire should never be maintained after the melting-point of cone No. 1. As a rule I have maintained in my experiments a heavy fire only up to the melting-point of gold. On proceeding in this manner the time allowed suffices to remove all of the reducing effects by an excess of oxygen in the fire-gases, and the most sensitive colors, the pink and the uranium-yellow always appear again; but if reduction is carried up to a higher temperature, many of these colors disappear entirely or they appear more or less changed.

It will be possible to use many of the usual whiteware colors sold, for the underglaze decoration of porcelain, but they are generally made so easily fusible by the addition of glazes that they are not always to be recommended for underglaze painting on porcelain since they are too strongly attacked by the glaze at the higher temperature involved. For this reason it is better to prepare the colors at the pottery.

As underglaze colors I have used the colors discussed in the article "Underglaze Colors and their Preparation," diluted with porcelain bodies up to 33⅓ per cent without observing any perceptible loss in coloring power. However, by the addition of body, they are protected more from the influence of the fused glaze than when they are applied pure. In addition to this, when compounded with porcelain body, they flow better from the brush so that they are more easily applied. The decoration applied on the biscuit-burned body must, of course, be again subjected to a low burn before glazing, in order to destroy the thick oil and oil of turpentine or glycerine mixed with the bodies. These colors used for the purpose of underglaze decoration are supposed to be covered with a colorless glaze. However, on using a colored glaze as a coating of which the light ones are best used especially light seladon and a bright yellow uranium glaze, produced by diluting the standard glazes with white, the colors used undergo a complete change in shade. It is best, in producing decorations under such colored glazes, to make some trial pieces with the underglaze colors on hand and to burn them coated with the colorless glaze, if undesirable colors are to be avoided.

UNDERGLAZE DECORATION BETWEEN TWO LAYERS OF GLAZE

Underglaze decoration still causes considerable difficulties, as we have seen if applied on the biscuit-burned body and with the ordinary white or light colored true porcelain glazes. First, of course, the color-scale is more limited than that for whiteware, and again the desired colors appear only in such kilns which permit of excluding, at least above the melting-point of gold, all smoke in the kiln space; by smoke they are always changed more or less. But with the Japanese porcelain it is quite feasible to use much more fusible glazes which still permit the fixing of the decoration in the muffle.

A glaze suitable for this purpose is obtained by maintaining the chemical composition of the porcelain glaze previously given, but introducing in place of the silicic acid contained in it an equivalent amount of the more fusible boracic acid. Such glazes adhere to the biscuit-burnt bodies as perfectly as the porcelain glazes mentioned.

I have carried out a series of experiments in this way and have found a suitable proportion to be that of replacing one-third of the silica present by boracic acid; in this way sufficiently fusible glazes are obtained. The glaze becomes smooth and transparent at a temperature which corresponds to the melting-point of 50 parts of silver and 50 parts of gold, thus not falling below the limit of temperature, which is employed in the whiteware industry for the melting of glazes.

The Japanese glaze No. 1 was taken as the starting-point for this glaze and in it a third of the total silica was replaced by an equivalent amount of boracic acid. By calculation the following composition is obtained:

	Parts.
Quartz sand	26.3
Marble	17.1
Crystallized borax	24.6
Hydrous boracic acid	27.2
	92.2=64 parts of fused frit.

These 64 parts of frit must be compounded with 33 parts of Zettlitz kaolin.

The ingredients of the frit are first melted thoroughly in a Hessian crucible, provided with a hole in the bottom, coke being used as fuel; the glass is cooled suddenly in water and ground in the mill together with kaolin in the above proportion. Although the frit forms an opaque milky glass, yet the glaze produced from it remains perfectly clear on slow cooling. This adheres, at the temperature of the melting-point of 50 parts of silver and 50 parts of gold, entirely free from cracks, even when melted over the porcelain glaze in a very thick layer, and shows a high gloss without perceptibly attacking the colors applied under it at this temperature.

In order to fix the decoration applied with "Zach" oil or oil of turpentine on the porcelain glaze, so that on subsequent glazing, it is not washed off, it is well to burn it strongly, at least at the melting-point of silver. For this reason it is also well to compound the whiteware colors with a trifle of a quite fusible whiteware glaze, so that they adhere better to the body. When the decoration is fixed, the glaze of the consistency of cream is poured over all parts of the piece, as it is done with biscuit-burned porcelain, the excess is removed by shaking and the object is dried rapidly in a hot stream of air.

It is thus possible to employ the usual color-scale of the whiteware underglaze colors on porcelain, and if the ware so decorated is not left unglazed, but is coated with a porcelain glaze, this gives to the decoration a special charm, for then the paintings appear to float between two transparent layers of glaze.

In the experiments which I have carried out, I have always made use of English underglaze colors, which I compounded with the whiteware barium glaze, mentioned in another place, in order to fix it better to the body, up to 20 per cent. In this manner it was even possible to produce a beautiful Persian red on the surface of the porcelain in the form of a paste applied over it. This is produced if a mixture of a clay burning to a nice red (for my experiments the Moschheim clay was selected) and quartz powder is compounded with a glaze high in iron. The proportion of Moschheim clay to ground quartz sand was:

46 parts of Moschheim clay,
54 parts of quartz sand.

For Persian red there were used:

50 parts of the preceding mixture, raw,
50 parts of the preceding mixture, burnt,
10 parts of flux containing iron.

The flux containing iron was produced from:

1 part of whiteware glaze, white,
1 part yellow uranium whiteware glaze,
2 parts of whiteware glaze containing iron.

These three bodies were obtained by fusing together:

	White whiteware glaze.	Yellow uranium glaze.	Brown iron glaze.
Potassium nitrate	101.0	50.5	50.5
Marble	50.0	238.0	25.0
Barium carbonate	98.5	49.25	49.25
Borax crystallized	191.0	95.5	95.5
Boracic acid, crystallized	24.8	86.8	86.8
Sand	288.0	288.0	288.0
Uranium oxide	——	225.0	——
Iron oxide	——	——	80.0

The addition of yellow uranium frit gives to the paste a yellowish-red cast.

EXAMINATION OF A FEW JAPANESE PORCELAIN COLORS

The use of colored enamels on the surface of the porcelain made it appear desirable to examine chemically also a few original Japanese colors, which were placed at my disposition partly by the firm Rex & Co., Berlin, partly by Dr. Wagner, in Tokio, in order to reproduce them, for the purpose of decorating porcelain in a manner similar to that customary with the Japanese. The colors were the following:

Iron-red from Kagosima, province of Kaga in Japan, by Messrs. Rex & Co.
Iron-red from Arita, province of Hizen, in Japan, by Dr. Wagner.
Powdered glass, a constituent of the porcelain colors, by Dr. Wagner.
Green porcelain color, from Arita, by Dr. Wagner.
Blue porcelain color, from Arita, by Dr. Wagner.

The first two colors are of the character of the European colors, that is, mixtures of pigments with a flux, which does not attack the color at the temperature employed in the fusion; the coloring body is thus kept in suspension in the flux, unchanged, after the firing. But the last two colors possess perfectly the character of the Japanese colors, that is, the coloring metallic oxides dissolve in the flux to a clear transparent enamel. The composition of the colors proved to be as follows:

	Red from Kagosima.	Red from Arita.	Powdered glass from Arita.	Green porcelain color from Arita.	Blue porcelain color from Arita.
Silica	28.90	38.95	47.25	37.76	34.84
Oxide of lead	47.00	39.29	45.07	46.81	45.92
Alumina	1.21	1.36	1.18	0.76	1.22
Ferric oxide	11.16	10.23			
Potash	3.38	4.03	5.65	4.77	5.58
Soda	1.77		0.13	0.62	0.30
Loss on ignition	6.52	6.88	0.72	4.77	9.27
Cobaltous oxide	——	——	——	——	2.79
Copper oxide	——	——	——	4.27	——

If one does not consider in these analyses the loss on ignition, nor the ferric oxide and alumina in the last three, which apparently are impurities, the composition of the colors is calculated as follows:

1. Kaga-red:
   $K_2O + 3.35PbO + 7.64SiO_2$ or $RO + 1.75SiO_2$.
2. Hizen red:
   $Na_2O + 2.71PbO + 9.98SiO_2$ or $RO + 2.69SiO_2$.
3. Glass used in color preparation:
   $K_2O + 3.26PbO + 12.70SiO_2$ or $RO + 2.98SiO_2$.
4. Green porcelain color:
   $K_2O + 0.89CuO + 3.43PbO + 10.30SiO_2$ or $RO + 1.92SiO_2$.
5. Blue porcelain color:
   $K_2O + 0.58CoO + 3.24PbO + 9.14SiO_2$ or $RO + 1.89SiO_2$.

The glass used in the making of the porcelain represents a normal flint glass, almost a trisilicate, with potash and lead oxide as bases. In the finished green and blue colors the degree of acidity does not quite correspond to the bisilicate, which leads us to suppose that besides the coloring metallic oxides, lead oxide is added in some form to the glass powder, about a third of the total basic fluxes. This assumption was verified by the statements which Dr. Wagner makes about the preparation of the porcelain colors. According to him they are composed of glass powder and white lead; to which for green, copper oxide is added; for blue, Chinese smalte; for red, *caput mortuum*. In the last, as is shown by its higher degree of acidity, the addition of lead oxide is smaller.

The blue and green enamels prepared according to the composition of the Japanese and applied on the porcelain in not too large surfaces, adhered well. But with very hard-burnt porcelain sometimes small crazes show on the enamels. These are not bisilicates and hence, according to what we know concerning the decomposition of glasses it cannot be expected that they should be of great durability. In fact they become dull in the air of the laboratory which often carries acid fumes after a few weeks. Since the barium enamel glazes reproduced for the decoration of porcelain after the Japanese materials, which I shall discuss in the following section, proved much more resistant to atmospheric influences, are harder and can be made in at least as many colors, there is no object in imitating the Japanese colors for this purpose. This may be done only in the making of the iron-red, because so far it has not been possible to produce it in equal intensity by means of fluxes free from lead. In order to imitate the Kaga-red the following frit was melted:

29 parts of sand,
49 parts of lead oxide,
7.7 parts potassium carbonate,
or 11.1 parts potassium nitrate.

To this was added iron oxide obtained by calcining iron sulphate slightly and washing, in the proportion:

	Parts.
Ferric oxide	12
Flux	88

The red can be applied on the Japanese porcelain even in very thick layers, without shelling off after burning and requires only a very low temperature for fixing, which is not above the heat required for gold decoration; it produces a brilliant color.

In order to make the Hizen red, it is necessary to take:

	Parts.
Sand	39
Lead oxide	41
Calcined soda	7

This is to be mixed with:

	Parts.
Ferric oxide	12
Flux	88

DECORATION WITH TRANSLUCENT AND OPAQUE ENAMELS

The transparent enamels given in the preceding section do not particularly incite reproduction, for on the one hand they consist of very soft and destructible lead glass, and on the other hand, though they adhered to porcelain, being glost-burned as soft as possible, they showed more or less cracking and shivering on very hard-burnt porcelain and especially in the decoration of larger surfaces. It was next tried to work with such colored glazes free from lead which I had used formerly for the color decoration of whiteware, only making them higher in alumina, in order to facilitate their adhesion to the porcelain glaze. In fact mixtures of 75 parts of barium whiteware glaze melted together with 25 parts of feldspar proved to be perfectly transparent glasses and suitable for the purpose.

For the decoration of porcelain with colored enamels the same system was followed as before in the decoration of whiteware. Colored frits of the same stoichiometric composition as the white frit, were produced in which half of the fluxes was replaced by colored metallic oxides. These could not be used as such even as colors, for they generally contain too much coloring oxide, the latter often segregating out, giving opaque glasses with a metallic gloss; but when they are properly compounded with colorless glaze they produced good, transparent glazes. The colorless transparent enamel of the formula

$$\left.\begin{array}{l}0.25BaO\\0.25CaO\\0.25K_2O\\0.25Na_2O\end{array}\right\} 2.4SiO_2 + 0.6B_2O_3$$

was obtained by melting together:

	Parts.
Potassium nitrate	101.0
Marble	50.0
Barium carbonate	98.5
Crystallized borax	191.0
Crystallized boric acid	24.8
Hohenbocka sand	288.0

The colored frits were produced from:

	Parts.
Potassium nitrate	50.5
Marble	25.0
Barium carbonate	49.25
Crystallized borax	95.50
Crystallized boric acid	86.80
Hohenbocka sand	288.00

To this mixture there was added:

	Parts.
Black cobalt oxide	80.3

or

Copper oxide	79.4
Nickel oxide	75.0
Ferric oxide	80.0
Uranium nitrate	225.0
Manganous manganic oxide	76.3
Chromium oxide	76.5

From the frits thus made the following enamels were prepared:

Green 1.—Dark yellowish green.
75 parts {
1 part copper frit,
2 parts iron frit,
1 part white frit,
25 parts feldspar.

Green 2.—Light yellowish green.
75 parts {
1 part copper frit,
9 parts uranium frit,
10 parts white frit,
25 parts feldspar.

Green 3.—Dark bluish green.
75 parts {
9 parts copper frit,
1 part uranium frit,
5 parts white frit,
25 parts feldspar.

Green 4.—Grass-green.
75 parts {
1 part copper frit,
1 part uranium frit,
2 parts white frit,
25 parts feldspar.

Yellow 1.—Deep yellow.
75 parts {
2 parts iron frit.
1 part uranium frit,
1 part white frit,
25 parts feldspar.

Yellow 2.—Lemon-yellow.
75 parts {
1 part uranium frit,
2 parts white frit,
25 parts feldspar.

Brown 1.—Yellowish brown.
75 parts {
3 parts iron frit,
1 part nickel frit,
2 parts white frit,
25 parts feldspar.

Brown 2.—Grayish brown.
75 parts {
1 part nickel frit,
4 parts white frit,
25 parts feldspar.

Brown 3.—Reddish brown.
75 parts {
1 part manganese frit,
2 parts white frit,
25 parts feldspar.

Blue 1.—Dark blue.
75 parts {
1 part cobalt frit,
2 parts white frit,
25 parts feldspar.

Blue 2.—Turquoise-blue.
75 parts {
1 part copper frit,
1 part white frit,
25 parts feldspar.

Blue 3.—Sky-blue.
75 parts {
1 part copper frit,
5 parts white frit,
25 parts feldspar.

Violet.
75 parts {
6 parts manganese frit,
1 part cobalt frit,
7 parts white frit,
25 parts feldspar.

Currant-red.
75 parts white frit.
25 parts feldspar.
0.10 part metallic gold as gold-purple.

Ruby-red.
75 parts white frit.
25 parts feldspar.
0.02 part metallic gold as gold-purple.

The preceding mixtures may serve as examples of colored relief enamels for Japanese porcelains. In order to make them lighter, it is only necessary to dilute them with colorless enamels, 75 parts of white frit and 25 parts of feldspar.

In the decoration with such enamels, for which the flower decorations in the Japanese style are particularly suited, the contours are first drawn with the pen upon the surface of the glazed porcelain; the contour designs are always applied with a mixture of the previously described underglaze colors with barium glaze in the proportion of 1 part of glaze to 2 parts of color.

The painting applied under the enamel, the shading, is carried out in the same manner. Where light had to be shown, this was accomplished by adding a mixture of 1 part of glazeand 1 part of porcelain body. Then the finely ground enamel was ground in water or with some mucilage or sugar and was applied with the brush or better with a pencil of hard wood or steel in a layer 1 to 2 mm. thick. Beautiful and rich in color as these decorations were, which were produced for some time, they were not quite satisfactory from the technical standpoint. The enamels were somewhat difficultly fusible; they required for good fusion a temperature of the melting-point of 50 parts of silver and 50 of gold, and this rendered a simultaneous application of gold in its alloys more difficult; also the pieces had to be burned alone in the muffle and no other decorations, which are generally fused at a lower heat, could be burned along with them.

These conditions induced me to go over to lead compounds for these decorations, which permit of descending to the temperature of the ordinary muffle-burn, that is, to about 700°–800° C. For this purpose, as it was necessary to lower the degree of acidity of the silicates, there had to be determined how far their content of alumina can be raised without dimming the enamels owing to the segregation of alumina compounds. Through a large number of experiments, whose details I shall not repeat because without interest, produced the result that a glass of the composition:

$$\left.\begin{matrix} 0.5BaO \\ 0.5Na_2O \end{matrix}\right\} 0.3Al_2O_3,\ 4SiO_2,\ 2B_2O_3$$

is admirably suited for the purpose and compounded with the coloring metallic oxides and with white lead, could be readily fused at the melting temperature of the ordinary muffle-colors. For a colorless frit, used for diluting the colored frits, the above glaze-frit was selected and it was compounded with one-half equivalent of lead oxide in the form of white lead. For this purpose there were fused together:

	Parts.
Barium carbonate	49.25
Crystallized borax	95.50
Zettlitz kaolin	38.70
Ground sand	102.00
Hydrous boracic acid	62.00

To this frit, after it was finely ground, there was added 19 per cent of lead oxide or 22.5 per cent of white lead in another grinding.

The following composition was used for the colored frits:

	Parts.
Barium carbonate	32.80
Crystallized borax	63.60
Zettlitz kaolin	38.70
Ground sand	102.00
Hydrous boracic acid	82.60

with the addition of a coloring metallic oxide, as:

	Parts.
For the iron frit, ferric oxide	13.33
or,	
For the copper frit, copper oxide	13.20
For the manganese frit, manganous manganic oxide	12.70
For the nickel frit, nickelous oxide	12.50
For the cobalt frit, cobaltous oxide	13.80
For the chromium frit, chromium oxide	12.75
For the uranium frit, uranium oxide	37.50

These colored frits are compounded like the white frits, with 19 per cent of lead oxide or 22.5 per cent of white lead after fine grinding.

With these colored enamels it was now possible to produce fine, colored glazes adhering to the porcelain glaze without cracking and of sufficient durability, which became smooth and transparent at the ordinary muffle-heat and could be burned together with the ordinary porcelain colors.

There was still lacking a kind of enamel which is opaque and can be applied as thick, semi-spherical drops on the porcelain (thus being very viscous), without flowing down like the colored enamels to form too thick a layer. This was accomplished with a glass flux very high in silica, of the composition

$$\left.\begin{array}{l}0.3K_2O\\0.7PbO\end{array}\right\}0.3Al_2O_3 + 5SiO_2 + B_2O_3$$

fused from the following composition:

	Parts.
Feldspar	83.55
Lead oxide	79.45
Sand	96.00
Hydrous boracic acid	62.00

The frit thus obtained was made into colored enamels by grinding it together with 10 per cent of underglaze colors; with these it formed bodies which could be applied quite thickly without flowing. They were chiefly used for border decorations and for the purpose of making pearl strings.

When the enamel was made white, which was accomplished by again melting it together with 15 per cent of tin oxide and again grinding it, it produced a very satisfactory layer for producing on a ground of colored glazes or Chinese-red a white, relief-like layer, on which decorations with ordinary porcelain colors could be applied. This technique was especially used for producing flower decorations on colored porcelain. For this purpose the enamel was applied on the colored layer, if necessary, up to 3 and 4 mm. in thickness on surfaces of any desired area of flat modeling; it was then burned in the muffle, and on the white surface thus produced the flower decoration was painted with porcelain colors for a second firing. In burning on the colors the white ground again becomes perfectly soft and the painting appears on it with a magnificent gloss, and especially so with deep colors. Such painting appears especially beautiful when it is applied on a ground of Chinese-red.

NOTE: Throughout this essay the lead oxide used in the various compositions is understood to be red lead, Pb_3O_4.

The term "Zach" oil probably stands for the oil of the Bohemian olive.

C. TRAVELING REPORTS AND LETTERS (POLEMICS)

I. LETTERS OF THE YEAR 1872

(Oldenburg, the Lower Rhine, Belgium and England)

The Oldenburg Clinkers (Vitrified Bricks)

ALBERT BLEININGER, B.SC., TRANSLATOR

Not every district is blessed by nature with materials which man may use in the construction of his dwellings and of his roads; in mountainous countries building-stones may be obtained, as a rule without trouble, of sufficient strength and durability; in one district there are available sandstones, in another slates, basalts, granites, limestones and various other rocks; the flat North German plain has its boulders, the shores of the Baltic Sea flints, in short, there is used whatever material may be most easily obtained. But on the other hand, there are sections which do not possess either of these materials, whose fields, moors, and meadows do not furnish even the boulders necessary for the pavement of the streets of cities and villages.

This lack must be compensated for, artificially and, naturally, it is the brick industry, which first of all, is called upon to fill this gap with its best, most durable products, and we observe that in such districts the manufacture of brick has reached its greatest development. We find in Germany that wherever the best natural building-materials exist the lowest grade of brick is manufactured, while in places where hard rocks are lacking these are replaced by vitrified bricks that indeed furnish a substitute which could not be better.

In such districts where the burnt stone rules over the natural rock, it is evident that higher requirements are made on the durability of a building brick. There such abominable lumps of clay crudely made from clay and gravel, which are found so often in our blessed Germany in all variations of workmanship and burning, are not known; a brick must equal the best rocks in strength, in fact must excel them in resisting power to the influence of air and water, frost and sunshine; such a product is the vitrified brick. The home of the clinker is found along the coast of the German Sea, Oldenburg, Friesland, Holland,—districts which possess no natural building-materials whatever, but are rich in deposits of fine plastic, ferruginous clay. The clinkers which are manufactured here must not be compared with the products which are called clinkers in the other parts of Germany. There the term comprises almost exclusively only such bricks whose production was not intentional but accidental, or is due to the method of burning or to the working of a particular kiln; only in isolated cases is vitrification brought about intentionally, in cases where the raw material is of such a character that it cannot be made to hold together without thorough vitrification.

In the coast districts of Oldenburg, as well as in Holland, the brick industry is of quite a different character; here the aim is the production of large quantities of clinkers, while the brick, called hard-burnt in the other parts of Germany, receive no consideration, and is considered only as a necessary evil. In this connection we must consider, however, that the clinkers are not only used in the construction of buildings, but first of all in the pavement of roads, a use which requires the greatest durability. Any one not acquainted with such a pavement can not have a proper conception of the ease with which loads are moved on it, even in the most unfavorable weather, and it is surprising how smooth these brick-paved roads are, how free from holes and ruts.

A clinker used on such a road is something out of the ordinary. As a rule, in the making of brick the main consideration is to produce an exact shape, since shape is the only standard by which bricks are judged; neither producer nor consumer cares about the interior of the brick, and if a specially durable brick is required the irregularity of the body which causes weakness is overcome by harder burning; but the effect of burning is not as complete as imagined. This fact is realized by the Oldenburg brickmaker, who strives to produce maximum strength by the most careful working of the clay, by means of the tempering wheel and pug mill followed by the most severe burning. By working in this manner it is possible to produce brick of such durability that will stand comparison with the hardest natural stones, granite or basalt.

The clinker roads are used for fifteen to twenty and even twenty-five years without requiring repairs while other roads must be remade every few years.

Not only roads require a durable material, but also the Oldenburg building-brick must be of a high grade. It is pleasure to pass through the fine villages built up of high-gabled clinker houses; nowhere are the brick walls plastered over; this is not necessary, since there is no occasion to protect such excellent brick from the influences of the weather. As to the technical part of the manufacture of these vitrified bricks, it does not materially differ from the usual method; however, more pains are taken to work the clay thoroughly and to burn it as hard as possible. The use of tempering wheels and pug mills is for this reason much more extensive in this district than elsewhere, and hence the clay is made more homogeneous than is customary in other places.

The burning of the vitrified bricks is accomplished with peat as fuel, which here is available everywhere, especially in the many small plants; the kilns used are the old roofed, open or arched up-draft kilns; however, near Oldenburg there are a number of larger establishments using continuous kilns, about half a dozen. These do as excellent work as can be done by any kiln. Just as here a product is manufactured which satisfies the highest demands in regard to quality, and also shows intelligent methods of manufacture, so also the continuous kilns of this district rank high as to uniformity of burning and economy of fuel consumption, surpassing all other kiln systems. It certainly is a good indication of the suitability of the continuous kiln for burning vitrified bricks that it has been found to be most satisfactory where the highest requirements are set for clinkers. The brickmaker can look with pride to his kiln and with contempt upon the other imperfect kiln systems. Better products are manufactured in no other part of Germany.

Of course, in order to accomplish such results intelligence is required, and any one who cares to see how a brickyard ought to be operated should go to the German sea-coast.

The Lower Rhine and Belgian Brick Industry

ALBERT BLEININGER, B.SC., TRANSLATOR

Every industry is carried on differently in different countries, and possesses certain peculiarities. This is also true of the brick industry, and when we describe the methods by which bricks are made in Belgium and in the districts of the lower Rhine, we do this because both possess a certain similarity and apparently the customs of one have been borrowed from the other. The differences are not always based upon differences in the treatment required by the various raw materials, but are associated with differences in taste, the manner of living and customs which are peculiar to the many nationalities; everywhere we find a certain preference for certain well-established appliances and tools, changes due to the climate and commercial conditions governed by geographical location. On traveling through the Rhine districts, and especially through southern Belgium, we find that brick-making occupies an entirely different position in the industry than in most parts of Germany. While in Germany we find on brickyards large buildings, machines, dryers, sheds and kilns, here we see nothing of the presence of such an industry, at least in most cases, but burnt clamps or large dumps; brickyards, in the ordinary sense, are found only in few places, especially favored by location. Most bricks are made for a definite purpose. If a building or factory is to be built, bricks are made at the nearest available location without the construction of expensive plants, sheds and kilns; sufficient space is leveled up and the bricks needed are molded from the clay, during the favorable season, hacked and, after completed drying, burnt in a clamp. This is the procedure in most cases as far as rural building is concerned. This method is, without doubt, best adapted for such temporary production, and if the burn is successful, owing to favorable weather, it also is the cheapest, but in most cases the weather conditions are not favorable and the results obtained are of the most discouraging kind.

Attempts have been made, but fortunately without success, to introduce this seemingly very practical method of making brick in other districts, and it seems advisable for this reason to show its defects in order to prevent a retrogression along this line in our German industry. At the same time a comparison is thus made possible with the Oldenburg and Dutch methods previously discussed.

Owing to the temporary character of the lower Rhenish and Flemish brickyards which furnish material only for one or a few buildings it is quite evident that no expensive machines can be put up; no pug mill or tempering pits can be used in order to give to the brick the required homogeneity; if it does not naturally possess the desired uniformity the working is restricted to spading or hoeing, distributing the water in this manner as much as possible, or occasionally the clay is trodden by the feet of the workmen; no drying racks are used, but the bricks are left long enough on the ground till they can be hacked; they are not protected from rain in sheds, but are covered at most only with straw or frames; after drying they are stacked up in clamps where they are burnt with coal which is filled in between the courses of brick, after the clamp has reached a certain size.

The molding is always done in sanded molds with a fixed bottom, the lump of clay also being rolled in sand; usually the bricks are molded so stiff that they can be set on edge immediately. It is surprising how rapidly the molding is carried on by the workmen who are employed at this work only during the warm season, and it is not a rare case to find that a molder with two boys, one of whom dumps the bricks from the mold and sands the latter, while the other carries off the brick pallets, makes 5,000 to 6,000 bricks a day, and even more; the molder has to cut off the required amount of clay from the pile, to roll it in sand and throw it into the mold, at the same time cutting off the excess of clay with a wire stretched across a curved piece of wood, something like a violin bow. After the drying which takes place in the pit itself in which the clay is dug, as does also the burning, the bricks are set in clamps with alternating layers of coal; the clamps hold from 30 to 300,000 bricks, and are set on fire through flues left open for this purpose. The admission of air during the burning which, according to the size of the clamps, lasts from fourteen days to six weeks is regulated by piercing the coating of clay around the walls of the clamps in places or again daubing them according to the judgment of the burner.

It is evident that such burning is entirely at the mercy of the elements, and that it can be carried out with some hope of success only during the summer, while the spring and fall months are doubtful and may cause heavy losses; as a rule, with a normal clamp burn, one-eighth of the bricks are waste, owing to melting and breaking; in unfavorable weather a waste of one-quarter to one-third is not rare, without assuming careless burning. The character of these bricks is shown by their appearance—they show an irregular, stony fracture, are cracked, rain-marked and crooked, and never ring, although burned hard.

Although the picture of the itinerant brick industry is rather a depressing one, yet there must be mentioned that in a few places favored by nature or by certain conditions of transportation brick plants have become permanent which often are large; although also in these the manufacture of brick is carried on as customary, still the conditions are such that more care can be taken and arrangements made to protect the ware from the weather. Also in plants of this character the manufacture of roofing tile is added, nearly always S-shaped, so-called Dutch tiles, and sometimes the production of floor tiles, for halls, usually blue-smoked; products of this kind require more care and part of the better handling may benefit the brick.

The greatest settlement of the brick industry in Belgium, whose products are the most desired, is near Antwerp, on the banks of the Schelde and Rupel; for hours brickyard after brickyard is noticed on the right bank of the Schelde. In order to show the magnitude of the industry I give the production of brick for the largest brick-making communities for the year 1871.

The production at Boom and Niel amounts to 200,000,000 bricks and a few million roofing tiles, paving tiles and some drain tile:

	Bricks.
At Rumpst - - - -	90,000,000
At Rupelmonde - - - -	100,000,000
At Burght - - - -	25,000,000
At Hoboken - - - -	10,000,000
At Hemixem - - - -	50,000,000

The number of brickyards at these places is more than one hundred. The size of the brick made here is much smaller than the German size, being 18 cm. by 8.5 cm. by 5 cm.

The manufacture here is about the same as in the other parts of Belgium, with the exception that the advantages of permanent establishments are available; the extremely fine and heavy clay dug directly behind the brickyards on the rising banks of the Schelde is allowed to weather and the bricks during drying are protected from the rain in sheds. The kilns are square, arched spaces, holding from 50,000 to 200,000 bricks, in which the burning is carried on in exactly the same way as in the clamps, but without the enormous losses caused by the lack of protection against the wind and weather.

There are always several of these kilns located alongside of each other, usually four to six; their long sides, carrying the arches, adjoin each other. The doors in one of the head walls are about 1.5 meters wide and reach nearly up to the arch; at the opposite head wall, close to the arch, there is an opening about 60 cm. square, which is connected with a flue joining all the kilns and which serves to draw the products of combustion into a high stack which is located outside of the kilns.

The bricks are set in these kilns so that three flues are set by means of the green brick, at the bottom, passing along the entire length of the kilns; these flues are set three bricks high and about 15 cm. wide. On top of the flues the bricks are set in three tight courses followed by a layer of coal; on top of the latter there are again set three tight courses of brick and so on up to the arch. The layers of coal are thickest at the bottom and gradually become thinner towards the top, the thickness having been determined by experience. When the kiln is filled the door is walled up with a double wall having a sand filling; at the bottom only, there is left an opening about 30 cm. wide and 45 cm. high which serves to start the fire and which admits the necessary air for combustion. Since the bricks are always set tight a very high stack is necessary in order to bring in the required amount of air. Such a kiln burns two to three weeks, according to its size, and certainly furnishes a better product than the clamps. The bricks, however, lack the clear ring and often show water-smoking cracks. These kilns are rather expensive to build and I believe I am not wrong when I consider their cost higher than that of a continuous kiln of equal capacity. The use of the ordinary clamps in larger permanent brick works is an impossibility for the reason that after several burns the waste would equal the cost of the permanent kilns, owing to the fact that the enormous amount of refuse could not be handled. Take, for instance, a brick plant with a capacity of 8,000,000 bricks, working with ordinary clamps; at least a million would be rejected as waste every year, and this would require a large area of waste space. In such plants, where for a definite purpose only one or two clamps are burnt, this waste in part is used for grading or in districts poor in sand, or in large establishments, like that of Krupp at Essen, it is ground up and used for making mortar. It is not suitable for roads since it consists of very soft burnt material.

For some time some of the more intelligent brickmakers have built continuous kilns, and these have not only proved successful in regard to decreased fuel consumption, but they also produce a better quality of brick.

Of special importance for the lower Rhine districts and

Flandern is the manufacture of the dark bluish-black paving and roofing tiles which are made from the same material as the red ware, also used, but obtain the color peculiar to them by a special process, the so-called blue-smoking perhaps not generally known. This process is said to give to the ware greater durability. The roofing tiles are S-shaped and known in Germany as "Dutch tile," and are also used extensively in Hessia and Thuringia.

The kilns used for the burning of the roofing tiles are oblong, 10 meters long, 4 meters wide and 3.5 meters high, arched over. Each of the two head walls has three openings closed by iron fire-doors, which correspond to the three grates passing from one end of the kiln to the other. The grates are charged with coal and hence possess also an ash-pit extending throughout the length of the grate. The grates, consisting of cast-iron bars, are 30 cm. wide and have slits about 0.5 cm. wide. In the arch there are fifteen holes, arranged in rows, for the escape of the fire-gases, which connect with a flue on top of the arch. The gases are thus conveyed to a main flue communicating with the stack.

The process of blue-smoking roofing tiles or brick is as follows: The lower part of the kiln is, as customary in burning roofing-tile, set with bricks or paving tiles; these are set so that fire-arches are formed in the usual way. These courses are about a meter high; on top of these there come the roofing-tiles set on edge, the projecting nibs being alternately on top and the bottom. The courses are alternatingly set skintling to the right and left. In order to avoid tipping during the shrinking a binding course is set crosswise every meter in height.

When the kiln is filled its content is burned exactly as if the tiles were to be red in color. As soon as the finishing temperature has been reached the flues on top of the kiln arch are uncovered at the places where they connect with the openings in the arch, and the openings themselves (excepting two or three) are tightly stopped up with bricks and clay. Thereupon green alder wood is charged into the firing flues, about eighteen sticks per burn for a kiln of the dimensions given, and the fire-holes as well as the ash-pit doors and the upper flue openings are walled up and daubed as rapidly as possible. The action of the heat on the green wood results in a large volume of gas and a thick smoke fills the entire kiln. These gases cannot burn since the necessary air is lacking and they now burn partially at the expense of the oxygen taken from the ferric oxide of the clay; the red ferric oxide combinations are thus changed to the black ferrous compounds.

Since this process through which the clay assumes the blackish blue color is reversed as soon as the evolution of gas from the wood ceases, the black ware is liable to turn red again as soon as air enters through the cracks of the kiln which can never be avoided. This is prevented by cooling the kiln as rapidly as possible after charging the wood, which is accomplished by evolving steam in the kiln from water poured on to the arch. In order to avoid a direct flow of water through the cracks of the kiln the sand covering the arch, the latter being 18 cm. thick, is moistened by sprinkling and is solidly tamped. Small dams of soft clay are put up around the arch holes and water is pumped or carried up so that it stands several centimeters deep on the arch and thus maintains a steady evolution of steam in the interior of the kiln which prevents the admission of air. It is obvious that such a radical procedure is bound to injure the kiln and arch seriously, and it is readily understood why the kilns undergo general repairs twice a year.

The roofing tiles thus blue-smoked withstand weathering much better than the red ware, and for this reason the wise council of the city of Ghent has decreed that all roof areas fronting the streets must be covered with blue tiles, and the use of red tiles is permitted only for back buildings and the sides turned towards the yards.

It is not absolutely necessary that alder wood be used for the process described; it may be replaced by other fuel, giving off a large volume of similar gases; for instance, the same effect could be produced by the introduction of coal-tar into the kiln, after the latter has been closed up air-tight; likewise in place of wetting the arch, the part of the kiln most easily injured, the kiln could be cooled rapidly by injecting a spray of water into the kiln, say, in the ash-pits. In this respect the Belgian brick industry is in the same position as the German—both adhere tenaciously to the old methods, showing an ignorance of their own business which exceeds all allowable limits. At the same time if some feel the necessity of improvement the lack of knowledge is shown by the attempts at innovations that usually result in dismal failures which again prevent others from carrying out really good ideas.

The Potteries of Staffordshire

ALBERT BLEININGER, B.SC., TRANSLATOR

There are few industrial districts which are as interesting as the pottery towns of Staffordshire, not only on account of their enormous size and the variety of manufacture, but in a still higher degree, owing to the general, world-renowned reputation enjoyed by the products manufactured here for a long time for their artistic and technical perfection.

The center of the Staffordshire potteries is at Stoke-upon-Trent, in the broad main and branch valleys of the Trent which here form a wide basin. The industry is concentrated in the towns of Longton, Fenton, Stoke, Etruria, Burslem and Longport, and a number of smaller places. On coming from Derby and entering Longton a peculiar view of this factory district is offered which in magnitude is equal to that of any of our industrial centers. The English towns spread over large areas, with their wide streets, low houses, and innumerable chimneys, which appear like organ pipes on the roofs, offer a peculiar appearance; the numerous towns and villages of this district appear as a single gigantic city eternally surrounded by a grayish yellow cloud of coal vapor. On passing through on the railway, hundreds of stacks of the many coal mines and iron works and the large cones of innumerable potters' kilns appear spectre-like on one side, disappearing again behind, alternating with deep clay pits, brickyards, storage places for building materials, coal, and iron. However, ceramic products of all sorts predominate everywhere —stoneware pipes, fire-brick, ordinary and black-glazed brick products, fine whiteware, earthenware, Parian and soft porcelain.

The potteries, particularly, require our attention, especially since these have given this district its world-wide reputation. It would be an erroneous assumption to say that the gigantic growth of the industry at this place is solely based upon local conditions; it is true the entire district contains rich deposits of coal, which are covered by large deposits of brick and fire-clay; it is also true that this is the center of a wide system of canals and railroads, but the principal materials of the manufacture of fine whiteware, the so-called earthenware, china and Parian porcelain, which to-day are characteristic of the district, are not found here; they are transported from other parts of England and Wales—for the largest part from Cornwallis, Derbyshire and Devonshire.

A large pottery industry has been in existence here since ancient times based on the excellent refractory clays found and upon the extremely favorable local conditions; at first the industry supplied only the wants of a narrow district, but owing to the work of men, whose names are written in golden letters in the history of nations, it attained the high degree of perfection and importance which we now find it to possess, and stands unexcelled: these men were the Nuremberg Ehler brothers, who carried their art to this place, and first of all Wedgwood, the grand master of the potters, to whom the high place of English pottery is mostly due.

The variety of clay products manufactured here is especially striking, and there is no product from the imitations of the Chinese and Japanese porcelain down to the common brick, that is not well represented here. By naming the various firms and their products we would exceed the space of this essay by far. It suffices to say that the ceramic establishments, without counting the numerous coal mines and iron works, are many hundreds in number, and thousands of kilns are in operation. The entire population of large and wealthy towns is directly or indirectly connected with the industry.

Magnitude and variety of the industry—the quantitative side—are not the only features which appear most prominent to the visitor and fills him with a certain awe of human thought and activity, but the quality as well. The durability of the products, the accuracy of the work, the elegancy, taste and beauty of the shape and decoration of the Staffordshire pottery, even of the most ordinary and cheapest ware, which is entirely lacking in the German pottery, must be admired, and this reveals why the English ware enjoys a world-wide reputation and markets far beyond the boundaries of England. We find here none of the crude cooking ware, heavy pitchers, crude plastic decorations and painting of our German works. Everything, even the most common ware, breathes a certain elegancy, reminding one of the beautiful, graceful shapes of Greek pottery, showing the influence of Wedgwood; the color decoration makes use of all the technical means available which we are accustomed to see only on the better and best products. Summing up, it is not the high quality of the materials, not a special skill which enables the Staffordshire potter to produce better products, not the higher price, but a certain sense of beauty and an active artistic competition which urges him to make finer ware than others. However, the potter has a good school behind him; Wedgwood's influence is still felt in this generation and is being maintained. Here the industry is conscious of its power and every one feels that only active progression can keep him over water in the broad stream; he feels that he can exist only by striving for the best possible products. At the same time the potter is too much of a practical business man to practice false economy (the inherited fault of our German tradesmen) in obtaining new advantages. The English potter realizes that this cannot be done without a good school and continued acquisition of knowledge; for this reason institutions have been founded which are designed to assist the pottery industry in maintaining its standing.

At Burslem, Stoke and Etruria, Wedgwood institutes have arisen (that is, potters' schools) which were founded by voluntary contributions without any government assistance, and are also maintained in this way; these schools possess libraries and collections, and teach all the arts and sciences which promote pottery. These institutes, originating from the realization that only hard study, practice and the contemplation of beautiful examples can keep up the high standing already reached, express this idea in their exterior, and may be regarded as being the only ornamental buildings of these places; everything else is adapted only to the purely practical requirements.

In examining the Staffordshire industry we may well neglect the more bulky products, as the ordinary and fire-brick, building terra-cotta, sewer-pipe, chimney-tops, etc., and pay more particular attention to the higher products, earthenware, whiteware and porcelain.

In considering the methods of manufacture of these products, owing to the great variety in the methods used by the many potteries, we cannot, of course, enter into all of the finer details, for the composition of the body and glaze, as well as the manner of decoration, is different in all works. We must restrict ourselves to give a general idea of the methods employed in order to show that the same high results can be obtained in other places if the work is attacked in the proper spirit.

As I have mentioned before the materials at hand are well suited for the manufacture of heavier products, for instance, of excellent fire-brick and sewer-pipe, but not all of the different materials which the potter requires for the making of the finer bodies are found here; there is perhaps not a single place in the world which in this respect fulfils all the conditions. There is no art in producing good ware when the materials used are only those which bountiful nature happened to supply. The greatness of industrial talent is shown in creating the required conditions, by supplying the necessary materials from other sources, and this very thing is brought out here very distinctly.

In former times, the potter was necessarily restricted to the natural stores of plastic material and produced ware as good or bad as the conditions happened to be, as we can observe in a hundred other places. However, progress was made and other materials than clay were brought into use for the purpose of increasing the beauty or durability; it was observed that other clays, used as additions, produced a better body color, that certain minerals, flint and Cornish stone, when mixed with the clay in the finely ground condition, produced greater density and strength, that bone-ash made the burnt clay translucent, and finally it came about that the finer products did not contain any of the native materials. The latter were then used in the construction of the kilns and the making of the saggars, and yet it cannot be said that the industry is not a native one. Or, should the manufacture be transferred to the place where the china clay alone is found, or the Cornish stone, or the flint, without having the other materials?

As a whole the raw materials are the same for all products only the mixtures differ, and hence the different classes of ware all possess a similar appearance. It is often difficult for the non-technical to distinguish between an earthenware and a white-ware plate, or between the latter and a porcelain plate, since this requires a knowledge of the characteristics of these products. The superficial appearance is the same in all; the body is always more or less white, the glaze thin, hard, glossy and free from cracks. The earthenware may be decorated with the same Chinese painting, over or under the glaze, as the finest porcelain.

In roughly outlining the character of the products manufactured here we shall first determine in how far the methods practiced differ from German conditions. By the term "earthenware" there is understood an opaque, more or less white, hard burned body carrying a very fusible colorless or colored transparent glaze, the ware being used for household pottery of all sorts and also for ornamental articles. It is decorated like porcelain by printing, painting, enameling and gilding, and in many cases it is as white as porcelain, but it never possesses the ring, hardness and durability of the latter. This kind of product without doubt represents the main production of this district. The body is composed of refractory clay from Devonshire and Derbyshire with larger or smaller additions of china clay, flint and Cornish stone. The latter is a kind of weathered granite from Cornwall~~is~~, very high in feldspar and free from mica. These products also include the sometimes very beautiful pottery made from the ordinary red brick clay found here which in part is slipped with a white or a colored clay, and in part is provided with a transparent glaze which is applied to the green body; the ware of this character is very often richly decorated or coated with a beautiful black enamel which forms a splendid background for the gold decoration.

The stoneware represents a denser somewhat translucent white or yellowish body with conchoidal fracture usually worked into water jugs, sanitary ware, wall tile, floor tile, etc. This body is perfectly dense and non-porous, and hence is usually provided only with a very thin salt glaze, although it is also used in the manufacture of household ware and covered with a transparent lead borax glaze. In this case the decoration consists of blue or green cobalt or chromium colors, or occasionally the body is covered with a colored clay engobe.

The Parian porcelain is a very translucent body used especially in the manufacture of statues and bric-a-brac, possesses a pale cream color and waxy appearance, but is very difficult to work owing to its large burning shrinkage, and hence can only be used for small objects. The body consists of china clay, Cornish stone and flint with a large addition of burnt bone-ash and usually does not carry a glaze, although often it is decorated by painting, enameling and gilding. The china porcelain is a body which in whiteness and transparency equals the German porcelain, but does not, by far, possess the hardness and durability of the real hard feldspar porcelain. It is composed of china clay, flint, Cornish stone and larger or smaller additions of bone-ash and carries a lead borax glaze.

Several of the works also produce the famous Wedgwood pottery and jasper ware, a kind of translucent biscuit porcelain. The hollow ware of this character is glazed only on the inside, and the plastic decorations are always of the Greek type, white and translucent, while the ground is of a matt, very uniform, blue, violet or green, being the most beautiful ware which has ever been produced. In addition there are to be mentioned the famous wall and floor tiles consisting of a colored whiteware body decorated in various patterns, sometimes of the inlaid character, and finally reproductions of ancient art pottery of all nations, ware in the Persian, Moorish, Italian, French and Mediaeval German style produced on a magnificent scale as pottery, tiles and building terra cotta in the richest variety.

In order to become acquainted with the method of manufacture let us enter one of the numerous factories and follow the separate manipulations in the production of the earthenware. Although in the various branches of the industry we will meet different body compositions, different glazes and different styles of decoration, yet at the same time we will become familiar with the outline of the processes used in the manufacture of Parian and china porcelain and whiteware for everywhere there is found the same accuracy, the same care, so that the principles of the one manufacturer may be applied without great modifications to the others; characteristic of the entire field of manufacture is the fact which does not apply to the German pottery industry, that the coarser material receives the same care in working as the finer, and everywhere the tendency is observed to manufacture ware from an inferior material whose appearance apparently approaches as closely as possible that of the best. This is the great secret of the superiority of English clay ware over the continental products that they represent, not the purely material character associated with the properties of the clay, but the spirit with which this clay is imbued by human work.

The pottery of Messrs. Pinder, Bourne & Co., in Burslem, is one of the larger earthenware potteries and we shall now examine it. On entering the works located in the center of the city we step into a labyrinth of courts and alleys in which we could not find our way without a guide. The separate kilns, perhaps a dozen, are located so far from each other that the turning, drying and glazing rooms, as well as all other additions necessary, could be built between them; only those rooms in which the bodies are prepared for the entire establishment, which we might consider as being composed of a number of small works, as well as the storage room are united in a larger main building. The rest of the plant consists of small one-story houses which, compared with German works, appear unsubstantial and irregular; however, the mild English climate permits such a wise economy, and hence the Staffordshire potteries seem to be laid out according to this one plan. In the main building which with its wings seems to project into the aggregation of kilns and houses collecting them into a whole, there are found in the upper stories the offices, magazines, decorating and gilding rooms, in the lower the shops for printing the decoration, the mills and washing apparatus and presses for the preparation of the bodies.

The several constituents which make up the plastic body are ground with water in a series of drag mills to a fine slip, in this case flint and Cornish stone, which afterwards are mixed with a slip of Devonshire clay and china clay.

The mills consist of round, flat wooden vats about 2.5 meters in diameter, whose floors are paved with quartz or flint blocks, the joints being filled up with porcelain fragments; in the center there is a vertical shaft carrying four strong wooden arms, which, on revolving, push around four quartz blocks weighing about 600 kg. In these mills the flint and Cornish stone used as additions to the clay are ground in water to an extremely fine slip which afterwards is mixed with the required amount of clay in an agitating tank. The latter which produces the clay slip is a round vat with a vertical shaft carrying a number of horizontal arms thus keeping the clay slip in constant agitation, and preventing the separation of the various constituents.

The fine clay slip of the consistency of rather thick cream, after being mixed most intimately with the other constituents mentioned above, is tapped off and before being run into a large cistern it is made to pass a number of sieves which are kept in constant vibration, in order to facilitate the passing of the slip and to reject the coarser particles automatically; the upper sieves are of brass and are the widest so as to hold back stones, roots, etc.; these are followed by finer ones down to the finest hair sieves. Such a differentiation of sieves, appears necessary in order that all coarser particles may be kept away from the finer, easily choked and torn hair sieves, thus preventing the accumulation of larger amounts of sand on the latter.

After this operation the body is a very fine slip, moderately thin, and is conveyed from the cistern by means of a pump to the filter press.

The filter presses, of which there are four, are composed of cells of corrugated walls; they are formed by putting together in a frame oak planks, about 2 meters long and 5 cm. thick, twenty in number, and connecting them by bolts so that they are kept apart a distance of from 2 to 3 cm. In each of these cells there is a pressing sack of so-called English leather, all of them being connected by means of tubes with a common feed pipe. These pressing sacks are now filled with slip pumped from the cistern; owing to the high pressure of the pump the water is separated from the solid clay, the former is removed through the pores of the pressing sack, and the latter remains. By means of the pump, clay slip is being constantly forced in till the pressure gauge on the pipe shows that no more slip can be supplied since the clay in the sacks has become so thick that it cannot be made to separate any more water by pressure.

The presses are now taken apart, the sacks opened, and the body is found to be in the shape of plates, about 2 meters long, 0.5 meter wide and 2 to 2.5 cm. thick, in a condition of stiffness in which it is suited for working on the wheel. But this does not finish the preparation of the body; the clay plates are now rolled up and fed into a pug mill, which makes the body still more homogeneous; finally the body is shaped into handy balls which are taken to boys who cut up the clay thoroughly before working and again "wedge" it thoroughly.

The turning is, as a rule, done in plaster molds on the ordinary wheel with a plaster disk, set in motion by a boy. Most of the products manufactured are decorated with plastic ornaments either on the inside or the outside according to the purpose for which they are designed, for instance, the plates and bowls with leaf and fruit wreaths on their edges, or on the central surface, jugs and pitchers with leaf ornaments, coat of arms, or figural representations on body and neck. Only such articles which have smooth surfaces on the inside and outside, and hence are to be turned smooth later on, are turned up in the ordinary manner. The clay balls, after they have been weighed, are flattened out on a plaster block by means of a plaster batter into round or oval, uniformly thick plates, according to the kind of object to be made, and the clay is then pressed into the mold on the wheel; by means of the hand and a piece of smooth leather or rubber it is firmly pressed into the contours of the mold; the exposed surface then is shaped by means of a template of glazed clay which also produces a perfectly smooth surface.

In separate small shops which always work only for one kiln there are as a rule only from two to three wheels; close to the wheels there is a drying room with racks along its walls on which the ware remaining in the plaster molds is set; in the middle there is an iron stove which maintains a temperature of from 30° to 40° C., in order that the plaster molds might be emptied as soon as possible and used again. All the pieces, molded in plaster, remain in the molds till nearly dry which, owing to the high temperature of the drying room, does not take long. Then they are again placed on a wheel, set loosely into the recess of the disk, and in a few rotations the seams caused by the molding are removed by means of a fine blade.

Ware which has only smooth surfaces, and hence is turned up without molds, is dried slower at a lower temperature and when stiff is turned smooth on the lathe by means of a steel blade or a glazed piece of clay. Likewise all pieces which require the putting on of handles, spouts or ornaments, are taken from the plaster molds in the stiff condition and the projections, also pressed in a plaster mold, are firmly united with the body of the piece, any seams being carefully trimmed and smoothened.

After complete drying the ware is burnt for the first time in the biscuit burn where it is brought to the highest temperature; in a second burn (the glost burn) it is heated to a lower temperature, owing to the fusibility of the glaze. The burning is always done in saggars of fire-clay of uniform size, elliptical, about 50 cm. long, 30 cm. wide and 20 to 25 cm. deep, the walls being 2 cm. thick. The saggars are built up in bungs, up to the arch, being filled with the green ware which, at least in the biscuit burn, is set without stilts and corks.

The kilns used almost exclusively for burning all kinds of pottery as well as for burning bricks and fire-clay ware, with but slight changes, are known as Staffordshire kilns adopted in all English pottery districts; they are circular, with a spherical arch, of about 4 meters diameter, and 3.5 meters height; along the circumference of the floor which slopes up gently towards the center there are arranged eight to ten fire-holes. In the middle of the kiln floor there is a circular opening which is connected by flues with each furnace; besides, every furnace has an opening at the level of the kiln floor into the kiln space proper, around which in order to break the flames entering from the grate, a bag wall is built up loosely to a height of 1.5 meters, of fire-brick, with numerous joints; in the center a similar stack of saggar rings is built up. The flame is drawn off in the middle of the arch through a large opening about 30 cm. in diameter and about ten smaller ones, above the skewbacks, which can be closed by plates. The entire kiln is surrounded by a cone-like structure of brick which on top narrows into a smoke-stack; it is the purpose of this mantle to protect the kiln from the weather. The kiln is bound by bands of flat wire cable.

When the kiln is set with filled saggars, the joints being closed and luted with thin strips of fire-clay, the kiln door is walled up and the firing begun. The fire is very slow at first, and is then raised to the most intense white heat, the burn being finished after thirty-six to forty hours. The furnaces are, as a rule, without grates, and for this reason only very good lump coal can be used. After the burn the kiln is again emptied, the ware taken from the saggars, brushed by means of a hair broom and taken to the glazing and decorating room.

The colors used are applied almost exclusively under the glaze and the manner of their application differs so much from the crude methods employed in our potteries, that we must examine these manipulations more closely.

The decoration with bands and rings on circular pottery does not offer anything new; for hollow ware this is done on the lathe, for flat ware on the wheel with a paint tube. However, the application of fine designs, leaves, wreaths, flowers and pictures by the printing process is very interesting and is carried out according to two different methods.

The first consists of engraving the designs or pictures on a copper plate and printing them by means of heated rolls on fine silk paper the color being a varnish into which the color to be used, cobalt for blue, manganese for brown and black, chromic oxide for green, is finely ground. The impressions are now cut from the paper-sheets, applied on the biscuit with the sticky, printed side to the surface and firmly pressed on by rubbing with a felt cloth.

The article to be decorated is then dipped in water which softens the paper and loosens it so that the printed designs are left clearly outlined on the biscuit. For colored decoration the outlines of the design are printed in this manner and the painting is completed with the brush, using colors ground in oil; the painting of relief decorations with colored glazes is also done by means of the brush.

In copper-plate printing with engraved designs only very fine lines can be produced in this manner; for this reason wherever larger, uniformly colored surfaces are to be used, another method must be applied by printing the decorations from raised plates of wood or stone with a sticky varnish on paper and transferring the varnish to the biscuit in the manner indicated above; after this the body is grounded, that is, coated with glue or albumen, and after complete drying the dust-like color is powdered on by means of a bunch of cotton or is rubbed on. After washing with water the glue is removed together with all the color which is outside of the design applied with varnish; at the same time the color adheres perfectly to the varnish and the pattern appears in sharp outlines on the piece.

All printed and painted objects must be freed from the oil used in fixing the colors, before the glaze can be applied because the glaze slip would not adhere on the oily film; this is done by heating the ware before glazing in a fire-clay muffle to red heat which destroys and burns the oil.

However, this rather expensive and complicated mode of decoration is not always applied; it is made use of only for such products which may be considered as a substitute for the more expensive porcelain, and which are intended to approach the latter in regard to decoration and painting. The method is much simpler for ordinary ware, although very tasteful ornaments are produced. Plain, that is, monochrome, arabesques, stars, points, borders consisting of repeated designs, etc., are applied by means of an ordinary sponge with colors ground in water. By means of a sharp knife a pattern is cut on a fine-pored, ordinary bathing-sponge, say a branch, an arabesque, etc. The sponge is saturated with the color-slip and the pattern stamped on the biscuit by touching the surface with the stamp.

The pottery is also often decorated with narrow or broad rings of white pipe-clay or of clay compounded with strongly coloring substances, like cobalt oxide, manganese, etc., especially on ware produced from the red or buff-burning fire-clay of the coal formation. These coatings are always applied before the handles are attached, that is, in the stiff condition, by rotating on the lathe, the paint-tube being the tool used. These white or colored stripes, being brought out prominently by the color contrast with the ground often are also used as ground for the application of leaf-wreaths or arabesques, which are carried out by stamping or by means of the brush, so that the greatest variety of this kind of decoration may be observed.

A very dainty decoration of pottery which can be carried out without any tools whatever, and which has never before been seen by the writer consists of moss or tree-like branched lines. This decoration is specially applicable to products which do not permit of a very artistic treatment. It is applied by rotating the piece to be decorated on the lathe, and tracing a ring by means of the paint tube, using the same or a differently colored clay. On this engobe, while it is still wet, a drop of a strongly colored liquid is allowed to fall which immediately spreads and forms tree-like figures as they may often be observed on the fractures of red clay, and which cannot be equaled by printing or painting in regard to daintiness and sharpness. If the liquid to be thus applied is a solution of chrome-alum the figures become green after burning; a solution of chloride of cobalt colors blue, a manganese sulphate solution violet to black, and by blending, all tints and shades may be obtained.

However, let as now return to our description of the process of manufacture. After the decoration has been applied, by painting or printing, and the oil burned off the ware is ready to be glazed.

The glaze which is used is remarkable for its extraordinary gloss and its freedom from crazing; it consists in part of the same substances as the body, and this is probably the cause why it adheres so well to the latter. The proportions of mixing fluctuate in the different potteries and quite considerably for the various products, and are everywhere considered secrets to be known only by a chosen few. It would not be instructive to give here definite proportions, as they must be modified for every clay. The substances from which the colorless glazes are produced are: flint (silica), china clay, Cornish-stone (feldspar), white lead and borax to which there is added as a rule a little cobalt to neutralize the somewhat yellow color of the body and glaze.

The glaze materials are ground in drag mills to the finest consistency, sieved through hair-sieves and the ware dipped into the milky liquid; the glaze slip is always very thin so that only a thin coating adheres to the ware.

After the glazing the ware is again set in saggars which in this case, however, are glazed on the inside but so that they cannot stick in the burning. Three-cornered strips of clay are placed on the bottom of the saggar and between the pieces stilts, points and hooks are inserted so that the ware is not damaged by the touching of the glazed surfaces. The ware is set in saggars and luted as in the biscuit burn.

The glaze is burnt on in the kilns described above, but the heat is not raised so high because the glaze melts at a lower temperature than that reached in the biscuit burn; on the top and the bottom a peep-hole is arranged in front of which there are placed saggars provided with openings. In the saggars, trials are set on small cups which are drawn by means of tongs for the purpose of judging the degree of burning.

This operation really ends the process but many pieces of artistic ware are decorated again by painting over the glaze, gilding, and the application of lusters, etc. This kind of treatment is peculiar to every individual piece, and we can hence neglect it.

In undertaking to describe the Staffordshire industry it was not the intention to give a complete picture of the pottery manufacture of this interesting district; the variety of products is so enormous that it furnishes a great deal of matter for our instruction. It was the intention only to show German potters how, by tireless study and never tiring zeal, it is possible to reach the highest level of the industry, and to prove that not only favorable conditions permitted the craftsmen to climb to a higher position than is found elsewhere but that intelligence and hard work are the cause of this industrial triumph. These results should also be striven for in other places. The German artistic crafts, especially sculpture, once the flower of civilization, are now in a stage of depression although not without a promise for the future. May they again rise and, following the example of foreign manufacturers, take the lead as they did before their decay caused by political conditions.

The Manufacture of Bricks in England

Albert Bleininger, B.Sc., Translator

In order to be able to appreciate the peculiarities observed in the process of manufacture it appears necessary first of all to examine the requirements governing the properties of artificial building material as fixed by the English architects. Therefore let us examine an English dwelling house. It is not necessary to consider its interior arrangement since this is entirely dependent on climatic conditions and fixed customs and we will examine only the exterior, that is, the part in which the building material used can be studied.

Even to the non-technical man, coming from the continent, it seems a most striking peculiarity that the English houses are so very small and without any decoration whatever so that the streets appear extremely monotonous. Although laboring under the disadvantage of monotony English architecture has one advantage, compensating to a certain extent for beauty, in the high grade of the building material in regard to durability, such as we do not find as a rule in Germany.

It is characteristic of English dwelling houses and of all other buildings with the exception of purely ornamental structures that plastering of the exterior walls is almost unknown. Wherever it is used, the plaster is a decorative and not a protecting feature of the wall. It is used on windows and doors, sills, and similar parts imitating more or less the usual natural stone; a building whose walls are completely plastered is very rare; however, there is found more frequently a coating of oil paint on brick walls in order to cover the efflorescence, especially pronounced where buff bricks are used.

This monotony in the exterior of the buildings, without any decided ornament, without any division of stories, without a pronounced projection of window arches and sills by relief ornaments or color and even without an eave trough does not apply to many, especially public buildings, hospitals, railroad stations, etc.; here the contrary is true, the fronts being overloaded either with plastic ornaments or with geometric figures and areas of colored, glazed and unglazed brick, mosaic tile and terra cotta. This ornamentation produces an unquiet effect, and its many colors are as unpleasant to the eye as the monotony of the ordinary building.

A decoration less pronounced than the one alluded to is often carried out by putting up the walls with differently colored brick according to a definite scheme; thus in many buildings built of buff brick all the stretchers on the outside are red brick as well as a third of the wall area, and also the door and the window arches are faced with red brick; or again the stretchers are black on a red back-ground. The reverse order is seldom found, the lighter color being always the predominating one.

English houses, as a rule, never have an outside plaster coating; this does not apply to large wall areas only, but also in a large part to the ornamental features (relief ornaments) where they are found. Of course boldly sculptured sandstone ornaments occupy first place for pillars, round columns, capitals, etc.; low relief ornaments, however, are often made of terra cotta, especially door and window trimmings, sills, friezes, medallions, etc.

From this short sketch it will be easily understood what the principal aims of the brick industry are. These are not as is the case in Germany and other countries, only to produce a material which is strong enough to carry the required load, possessing approximately a regular shape, without taking pains to remove small irregularities and blemishes, since these are hidden by the wide joints, and also by a plaster coating, but on the contrary here the bricks are to be of the greatest possible regularity in shape and colors and must possess the greatest durability. In how far the English brickmaker has attained this end is shown by the inspection of any building in course of construction, or any brick-works. It does not seem a very patriotic undertaking to look for the good only in foreign lands and to praise foreign in preference to the home products, but it also is not well to indulge in a feeling of self-sufficiency in regard to the home products and to consider them superior to every other. Although we must concede that a lively competitive spirit has of late been shown in our industry partly due to the endeavors of the German Brickmakers Society, yet we cannot help but recognize that the manufacture of ceramic building materials is still inferior to that of the English sister industries, although in some respects, for instance, in the rational use of fuel, we are superior to them. There is yet much to do and many of our faults must be dropped before the German industry can equal the English.

Yet it is not our intention to render a one-sided judgment, and to burden the brickmakers with all the responsibility for the low condition of their industry; there are other causes, to say nothing of the lack of self-consciousness caused by political conditions, which in many directions have been a drawback; a part of the responsibility falls upon the architect. If our German architects had realized at an earlier date what an invaluable material they possessed in well made and durable brick for ordinary building purposes as well as for ornamentation in terra cotta, if they had insisted upon higher requirements as they are commencing to do to-day the brick industry would have undertaken the more general manufacture of face brick and the decoration of German buildings would certainly be more tasteful than that employed by English architecture.

The fact remains, however, that the average English brick is a better product than the German, owing to the more careful working of the clay, imparting to the product properties suitable to its purpose. The English bricks excel by their thorough homogeneity and before all by their great regularity in shape even as regards the ordinary bricks which are handled very carefully in order to prevent the breaking of the edges and corners; we in Germany could well afford to imitate this part. This fact also permits the bricklayer to build with much closer joints, uniting the bricks with a smaller amount of mortar—a condition which is of great importance in the construction of brick fronts.

In order to show how in England such perfect bricks are manufactured it may prove advantageous to investigate the methods of working in different places and with different materials and we will begin with the most common class of manufacture, which we might call the itinerant brick industry. The latter is located near the site of buildings under construction and its clamp kilns are found in all London suburbs.

The raw material is not difficult to find for London lies in a basin which is filled with an enormous deposit of a very fine, uniform and extremely pure and plastic clay. Sand, as a rule, is also found close by and the brickyard or brick-field is readily established, usually on rented or leased ground in the vicinity of the buildings under construction for which the material is to be furnished. The question arises now: How can bricks be made, suitable for brick fronts, without any preparation, without a plant, dryer and kiln, especially since the bricks are to be used not for rural building, but for structures in the English capital? Yet it is possible, and though the product is not a face brick, as we understand the term, yet it is a brick, which in regard to shape may compete with any soft molded brick made; the secret is that the brick is not handled from the moment it leaves the mold till it is set in the kiln perfectly dry.

In the late fall and winter the clay and sand are dug, the latter being screened; the quantity stored is sufficient for the prospective building of the next year. The two materials are spread out in alternating layers about 15 cm. thick, forming large quadrilateral and regular heaps; these are sprinkled by means of a hose and allowed to weather for weeks or months, according to whether the preparation was begun sooner or later. In place of the sand screened coal ash may be used. As soon as in spring the ice has disappeared the process of the preliminary mixing and soaking is continued and especially promoted by digging over the entire heap. The material is dug down in vertical sections, the clay and sand thus loosened being made up into a similar heap behind the first one. During this digging water is again applied to the material, if necessary, the soaking being continued for some weeks till the weather has become warm enough for molding bricks. Meanwhile all the necessary preparations for the manufacture proper, are made, the pug mill and machine are put up, and the drying space is leveled and graded so that work may commence at once.

In England, and especially in London, wages are very high and power is hence used as much as possible, which also applies to this simple process of making brick. For each of the clay heaps dug during the winter or for two of them a number of pug mills are put up in a straight line according to the amount or number of the bricks to be made. These machines are to soften the clay, to mix it thoroughly with the sand added or the coal ash, producing a homogeneous mass. Occasionally this work is done by horse-power, but usually by steam. A portable engine is put up in a suitable place from which power is transmitted by rope or wire cable to the pug mills.

After the clay has been made into a homogeneous mass of the proper consistency the molding of the bricks commences for which purpose the striking tables are, as a rule, placed close to the pug mill. There is to be mentioned that English brick molders not only work with stiffer clay than is customary in Germany so that the brick may at once be set on edge thus avoiding the work of edging and any finger marks and other damages, but they also make use of a few manipulations by means of which they avoid touching the brick with the hands entirely, thus maintaining the original shape. In removing the bricks there are used two small boards of smooth, hard wood as wide as the brick, about 1 cm. thick and 35 cm. long. One of these pallets is used in molding as the bottom of the molding frame; the brick is molded in the ordinary manner with sand or water and the off-bearer puts the second board on top of the brick, thus pressing down the edges of the brick drawn out more or less by removing the mold. The brick is then carried to the drying place and is allowed to slip from between the small boards so that a space is left between the bricks of the thickness of the board. When in this manner a row of bricks has been laid down, the brickmaker turns to another part of the drying place till, after one or two days, the bricks are sufficiently dried to carry a second row without being marked, and in this manner course on course is set up as high as possible. It is thus seen that the edging, etc., is entirely avoided representing an economy which cannot be too highly appreciated, and there results a brick which leaves nothing to be desired. The bricks are protected from rain, or if necessary from the sun, by being covered with straw, or by narrow shingle or straw roofs set on posts, or easily transported shingle or rush roofs. When the drying places are very large, which is true especially in machine molding, the bricks, of course, are not carried singly but are placed on trucks holding twenty-four bricks, in order to avoid damaging the latter, and are thus wheeled to the hacks and handled between two boards as described above.

Hand molding is practiced only to a small extent, at least as far as the vicinity of London is concerned, and since England is to a high degree a country employing machinery as much as possible, the brick machines have also taken the lead in the temporary brickyards. There is especially one machine which must be mentioned because the method of its working seems to be borrowed from the hand-molding process, and because with little help it produces a very large number of sharp-edged fine bricks if the clay is furnished sufficiently prepared. It is the machine manufactured by P. Bawden & Co. The machine consists of a vertical pug mill, whose purpose, however, is not to mix the clay, but to force out a uniform stream through a wide die; beneath the die there is a table, possessing a reciprocating motion, worked by an eccentric on the shaft passing through the pugging cylinder. The wooden mold boxes well sanded and containing the molds for six bricks are placed on this table; these by a forward motion of the table are pushed beneath the stream of clay so that the latter covers the mold; an iron plate possessing an up-and-down motion is now pressed upon the stream of clay and fills the six divisions of the molding box; when this has been done an empty box is inserted which at the same time expels the filled molds, cutting off most of the excess of clay by forcing it through an opening of the height of the mold. It is now necessary only to smoothen the bricks with a piece of wood and to place them on pallets set on trucks. In order to make possible the complete filling of the molds by the clay, the bottom of the mold is not tight but has two narrow slits of the length of the brick which allow the air to escape towards the bottom and permit the pressing in of the clay from above.

Such a machine worked by a horse, when using soft clay of the proper consistency, with one man for taking off, one for sanding and pushing in the mold boxes, two wheelers, and three off-bearers, together seven men, makes from 12,000 to 16,000 nicely molded bricks. The machine is portable and is so set up on timbers in a pit that there is sufficient room for the horse; these machines are also often driven by steam power.

The burning of the brick made in this way is done, as a rule, in the middle of the drying places, in a clamp kiln using slack coal, as soon as a sufficient number of air-dried bricks have been made and offers nothing new. For this reason we will not stop to consider the burning in detail since in a former letter this method of burning has been described in connection with the Belgium brick industries, in which also the defects of this method of burning have been pointed out.

The process just described is that which is used in the manufacture of the most common bricks burnt very hard, and which, owing to the careful preparation of the clay, are damaged less by the burning in clamps than the brick of the Belgium process. The bricks appear perfectly straight and sharp-edged, but of course they are not uniform in color and could not satisfy higher requirements. I will now ask the reader to follow me to another brickyard whose products, though not more durable, have a better color—the works of the Burham Brick Company, near Snodland, Kent.

This brickyard located near the mouth of the Medway is well-known owing to the high quality of its products, brick and terra cotta, especially in London, where the buff brick are very well liked. The clay is the same as that used by the ordinary London brickyard, the so-called gault or London clay. The capacity of this establishment is 15,000,000 to 20,000,000 per year, not only face and common brick, but also terra cotta and large four-sided and hexagonal pipes, which, filled with concrete and crushed granite, are also used as building material. At the same time the enormous chalk deposits below the clay are used in connection with the latter in the manufacture of cement. In the clay banks located near the works in which the clay is 10 to 12 meters deep, the clay is dug in the winter and treated as has been described above; it is heaped up in alternating layers with sand on the bottom of the bank, sprinkled with water and soaked for as long a time as possible. From the clay bank an inclined track leads to the machine building to which the material is conveyed by means of a chain wound around a drum and where it is fed to the brick presses.

Before being conveyed to the machine, however, it is again spaded over in the bank, and if necessary again sprinkled with water.

The large machine house located in the middle of the drying places contains, beside a steam engine of 250 horsepower, four plain rolls for the crushing of the clay, and ten Clayton brick presses of which each can furnish 12,000 to 15,000 bricks; each has a powerful pug mill for preparing the clay. The Clayton press, which is much used in the brick industry, is built according to the principle of the Sachsenberg machine so frequently found in Germany. The clay being pressed out of the pug mill in a uniform stream is forced over a roller table to the press. Here it is caught by a pair of inclined rollers and forced into the molding cylinder. From this it is forced through a conical bronze die, whose polished surfaces have a peculiar shape designed to prevent sticking and cracking of the clay in the corners. After it has passed two rolls, one on each side of the die, which serve the purpose of guiding the clay, the stream is forced onto the roller table on which a piece of the column is cut off by means of a wire close to the die. This piece is long enough for twelve bricks, leaving two small pieces at the two ends which it is necessary to touch with the hand. This piece is now shoved on to the cutting table proper. The cutting table differs from the German machine inasmuch as it appears as an independent machine, which does not cut the column of clay as it leaves the machine.

A piece of the column is pushed on to the cutting table over rollers, running in oil, which oil the lower surface of the column and the stream of clay is cut so that the bricks need not be touched in putting them on the barrow. The clay is not cut by moving wires but by means of a board which is set in motion by a lever forcing the column of clay against fixed wires, and after passing these it is placed on a board; the latter, together with the twelve bricks thus obtained, is placed on the barrow and replaced by a new board. From the machine the bricks are taken on spring barrows, to the drying sheds arranged at the two sides of the machine house. Here they are set down from the barrow by means of a two-pronged fork, thus again avoiding touching them with the hand. The shed roofs of the drying place, between which there is left a space of about 1.5 meters for wheeling in the barrows, are narrow two-sided roofs about 1.6 meters high supported by posts and covered with shingles. They protect the brick hacks sufficiently from the weather; the bricks are hacked gradually, as fast as the lower courses are dried and become stiff enough to carry more brick. In the upper stories and in the wings of the machine building there are found machines for making terra cotta, hollow blocks and the represses for shape brick. The larger building ornaments are as rule molded in plaster molds and there is only one kind of brick which demands our special interest since these are made in great variety and to a perfection probably attained by no other works.

These ornamental bricks are decorated on one or two sides with leaf ornaments, geometric figures, palmettos, etc., which are so arranged that in the wall they produce a continuous ornament. The number of patterns which are used here for the decoration of sills, door and window trimmings, arches and medallions, as they are seen in various London buildings, is a very large one. According to the data obtained by the writer 600,000 of these bricks were manufactured last year in 142 different patterns, and the care given to this sort of work was richly repaid. The manufacture of these bricks is indeed very simple, so that the cost is probably not much larger than for repressed brick. The press used in making these bricks is patented for England by Henry Peters. To a heavy horizontal shaft there is connected a mold consisting of one bottom piece and four side plates, fastened by hinges. The plunger plate is moved up and down by means of a screw and a heavy wheel. The mechanism is so arranged that a brick, fresh from the stiff clay machine, is placed on the bottom plate and the plunger is allowed to descend. At the same time by means of a cam the four side plates move together, a pressure thus being exerted from all sides at the same time. The mold pieces for making the ornaments are of iron and are readily fastened to the plunger plate or to the side plates by means of bolts. It is thus seen that the brick can be ornamented on five sides, if so desired, and also on several at the same time since after raising the plunger the side plates also return to their original position, leaving the brick resting free on the bottom plate. Each machine has on its shaft two of such folding molds, one for the pressing of stretchers, the other for headers, so that the shaft need only be turned and another mold bolted on if it is desired to produce other patterns. According to the information obtained either of these presses produces a thousand bricks per day.

All the products are burned in so-called Scotch kilns usually employed in England which are very similar to our ordinary open kilns in construction and method of burning. They consist of an oblong kiln space, 3 meters high, 4 meters wide and 10 to 12 meters long. They have at each of the two lateral sides a door for filling and drawing. Along the longitudinal sides there are arranged small fire-holes spaced at a distance of 1 meter, which are 16 cm. high and 15 cm. wide. In the middle these are divided by a projected brick into two parts. The fire-holes are so arranged that two are always opposite each other, permitting the building up of a firing flue going from fire-hole to fire-hole. The furnaces are without grates and can only be fired with lump coal; the upper half of the furnace is filled with fresh coal while the lower part receives the coke produced which from time to time is pushed into the firing flue.

The fire is regulated by covering the top of the filled kiln with a platting of waste brick, but owing to the large area of the hearth this naturally offers great difficulties, especially in bad weather. This platting is covered more or less by ashes according to whether the air circulation is to be stopped entirely, or whether in some places it is necessary to cause a stronger draft for the fire.

Of such kilns which hold from 100,000 to 130,000 bricks, thirty are put up, in two rows, in which all products are burned.

It is thus seen from the description of the process of manufacture practiced in the southern part of England that it does not vary to any large extent from German practice. The superiority of the English process is due only to the greater care with which the body is prepared and the more regular shape; the economic superiority is due to the use of machines and the most perfect subdivision of labor. The English brickmaker does only one kind of work, that is, one man does not dig clay, temper, mold and burn, but he is restricted to one of these occupations.

In the northern counties the brickworks are developed in an entirely different direction; although there the requirements of the architect are the same as in the south, the raw materials of that district have caused a deviation from the ordinary method and, so to speak, have made brick factories out of brickyards. The difference is a very decided one. The brick industry now to be discussed is located in York-, Lincoln-, Lancaster-, Chester-, and Nottinghamshire. Here the brick works are especially located near the coal regions of this district. The raw material of this industry is a clay very impervious to water or rather it is a shale clay associated with the coal measures which requires years of weathering before it becomes plastic enough to be made into a brick by the ordinary method of molding, by hand or machine. The difficulties due to the character of the material have led to processes employing machinery which reduce the weathering, for which nature requires a number of years, to a very short time. It will surprise the reader when I say that the material taken from the bank in the course of half an hour or an hour is set in the continuous kiln in the shape of brick. The clay is not subjected to a softening process, but in the condition in which it is taken from the ground it is finely powdered and the clay powder pressed into brick, tiles and shape brick by the application of a very high pressure.

In principle this is the same method whose introduction has been attempted in Germany yet without success since it resulted in ware which did not answer the requirements for good brick. However, when examining the differences between the attempts which proved failures in Germany and the successful realization in England, the causes of the failures are also explained. With us we deal with attempts to make good brick from unprepared clay by means of machines with large capacities, at least as advertised ; on the other side there are enormous machines worked by steam and in which the greatest part of the power is used in the preparation of the clay.

Some will now say that the material in itself requires a great deal of power in order to be at all suitable for the making of brick, for it is evident that brick cannot be made by pressing together shale and burning it. However, dry pressing has been introduced not only for non- or but slightly plastic raw materials, but also for plastic clays, and in many places common brick used as front brick, face and ornamental brick as well as terra cotta and floor tiles are dry pressed from unweathered clay; weathering in England does not stand for much, owing to the fact that the climate is so much milder than the German.

The clay, as deposited by nature, always has a stratified structure, and all the operations of weathering, soaking, tempering, and working in tempering pits and pug mills are intended to destroy this structure and to make the clay sufficiently homogeneous so that it may be made into various products without cracking and irregular shrinkage, or without being destroyed by weathering later on. In the industry of northern England this structure is destroyed by powdering the material, and the purpose intended is attained the more thoroughly the finer the powder to which the clay is ground.

The English brick works of this character are distinguished in their exterior from brickyards of the other types by the absence of dryers of any kind ; for this reason they occupy a much smaller area than that which we are accustomed to see in connection with our brick plants. They consist of a continuous kiln, or a corresponding number of Scotch kilns, a machine house and the clay-pit which, as a rule, is connected with the machine by a track. Before I describe a few of the most common machines I shall briefly indicate the various operations.

After the clay has been dug in the pit, it is loaded into cars which are taken to the machine; if the track has a steep grade the cars are hauled by cable. The clay is first dumped into one or two dry pans, in which not the mullers but the bottom plate rotates; the latter consists of a thick cast-iron plate. The shaft of the mullers runs in a box which can move up and down in a slot. The bottom plate has a high rim and a diameter of about 2 to 2.5 meters. The exterior half of the diameter of the bottom is perforated, screen-like, by small holes or slits through which the fine portion of the ground clay is removed and is discharged into a sheet-iron box below the mill. From the latter the clay powder is elevated to a higher story where it is passed through a screen which removes all the coarser particles, up to the size of a pin head; the material of this fineness is taken to the press and made into bricks. The coarser material remaining on the sieve is returned to the dry pan or to the disintegrator where it is ground again. The clay powder is taken to the powerful presses of which there are a great number of constructions; these machines produce bricks with very sharp corners and edges and so dense and smooth that they may be set on barrows like dry bricks and taken into the kilns. The green pressed bricks are so hard that they can be set up to the arch without danger of crushing, in fact they are harder than perfectly dry bricks made by the ordinary process so that it is not necessary to handle them very gently. The first operation to which the bricks in the kiln are now subjected is that of drying and water-smoking. This is done to remove the moisture contained in the clay as it comes from the bank, and if proper attention is not paid to this point the bricks become strongly whitewashed so that they could not be used as front brick which is the important thing in England. This drying and water-smoking in the Scotch kilns is accomplished by maintaining a low fire for some time, the difference from the ordinary process of manufacture being that it must be continued for a longer time than is the case with perfectly dry brick. In using the continuous kiln the water-smoking is carried out quite differently. Each chamber is disconnected from the rest of the kiln and in the kiln door the water-smoking fire is maintained on a temporary grate arranged in a wide opening of the door, thus permitting a large current of air to enter the kiln. Sometimes two chambers are disconnected, each independently, three partitions being used in this case. The hot air enters the freshly set kiln chamber and the moisture being expelled is removed at first through the open fire-holes in an upward direction; later, after the fire-holes are closed and the damper of the chamber has been drawn, the water vapors go into the stack. Another method of expelling the moisture, and thus avoiding efflorescence, consists in closing the door immediately after filling the chamber, and in placing on top of each firing hole a small water-smoking furnace so that air may enter in all portions of the arch; the moisture thus expelled in this case escapes at once into the smoke flue and the stack. The water-smoking furnaces consist of a cast-iron cylinder, 40 cm. high and 20 cm. wide, which in the lower part has a grate and fits into the sand trough of the firing hole. On the grate a fire is now built with rather poor fuel (cinders from the boiler furnaces or slack), and the air, drawn into the kiln by the draft of the stack, can enter the kiln chamber only by passing through these small fires and thus being heated. A third kind of water-smoking is carried out by means of a larger water-smoking furnace which is portable and sometimes provided with wheels, being located on top of the arch. This water-smoking furnace consists of a sheet-iron cylinder lined with fire-brick so that a firing shaft is produced about 1 meter deep and 25 to 30 cm. wide. The bottom is closed by an iron grate. The fuel is charged into the opening on top which is covered by an iron plate; close to the upper opening four pipes are attached to the side of the furnace for drawing off the hot gases, these being connected with four fire-holes by means of bent tubes; the heated air is thus drawn into the kiln by the draft of the stack. Another, fourth method of water-smoking which is introduced in many new continuous kilns, and which has proved very successful, employs a water-smoking flue arranged between the line of chambers and the main smoke-collecting flue; in this arrangement the warm air used for drying is taken from the empty kiln chambers, which are cooling, and hence a special furnace is not necessary.

In whatever way the water-smoking may be done, it must be continued till the bricks have been dried sufficiently and preheated so that nowhere moisture is deposited from the fire-gases on the surfaces of the bricks. If this is not done, uniformly colored front brick cannot be produced. As soon as the water-smoking between the dampers is completed, which, as a rule, requires forty-eight hours, the water-smoked chamber is connected with the fire by drawing the damper, and the separate water-smoking of the next disconnected chamber is begun.

The bricks burned in this manner are sufficiently hard only when vitrified; soft-burned bricks are more readily destroyed than soft bricks made by the plastic process; for this reason the burning is always conducted very carefully.

Hard burning of the brick is made easier by the method of manufacture itself, since the body when subjected to a high pressure becomes more dense than our machine-made brick ; the consequence is that it shrinks less and is not as liable to warp and crush. At the same time the bricks may be cut in all directions and are very regular in shape; they also show a toughness which, as a rule, is peculiar only to high-grade fire-brick, and is due to the pressing of the brick from a grain-like clay powder. The resistance to abrasion is so great that it is not customary to load the brick regularly on a cart, but they are thrown into the wagon box in any way, and on arriving at the place of building the bricks are simply dumped on the ground.

There only remains the discussion of the presses, which unite the loose but damp clay powder to a dense, compact body. Among the different systems, I will discuss here only two of the most prominent ones, which probably answer best the purpose intended.

The machine made by Bradley and Craven, in Wakefield, Yorkshire, produces 15,000 bricks in ten hours. The power required to run this press, together with the clay elevator, two dry pans and screens, is twenty to twenty-five horse-power. It consists of a thick horizontal table rotating about a vertical shaft, and in which there are twelve openings of the size of the brick to be pressed, 9 inches long, 4.5 inches wide, 3 inches deep. This table is rotated in regular intervals from a large wheel provided with three cams. The openings of the table are closed below by plates which move up and down in a guide, the brick being raised by the upward motion. The latter is imparted to the plates by being connected with rolls which on rotation of the table follow a spiral-shaped track, going up and down. From above, two wooden boxes are in contact with the table which supply the clay powder. There are also located opposite each other two plungers, which by a powerful eccentric receive an up-and-down motion. Let us now observe the working of the machine, assuming that an empty mold opening has arrived beneath the wooden box bringing in the clay and the bottom plate has reached its lowest position; the mold is filled with loose clay powder of which any excess is scraped off by the edge of the box at the next turn of the table. At the next interval the two plungers enter the filled molds and exert a slow but very powerful pressure upon the clay; this done, they again rise. As the table continues to revolve the bottom plate raises and lifts up the brick. The empty mold arrives at the second supply pipe, with its bottom plate in the lowest position; it is again filled with clay powder ready for the pressing of another brick. The table as well as the plungers are hollow castings which are kept hot by steam thus preventing the sticking of the clay powder to the mold; the bricks hence always appear with bright polished faces and the use of oil becomes unnecessary.

The second machine, though requiring more power (thirty to thirty-five horse-power) including its accessory machines, yet seems to be used more extensively. This is the press made by Platt Brothers, in Oldham, Lancashire. This may be due to the fact that the mechanism is simplified by doing away with the revolving table, and that the bricks are pressed, not by a one-sided pressure from the top, but also at the same time from the bottom, the clay being thus pressed more uniformly. The clay newly taken from the bank is also first ground in dry pans, screened and the coarse particles are again crushed. Four molds are let into a very heavy metal table; for each of the four molds a plunger is arranged receiving its motion from an eccentric. The molds are closed below by four more plungers likewise moved by eccentrics, which not only lift the pressed brick from the molds, but which also, owing to the peculiar shape of the eccentric, possess a slight upward motion while pressure is being exerted from above so that a pressure is applied to the clay powder from two sides. While the lower plates as well as the plungers have reached their highest position, the brick thus having been raised, a charging box filled with clay powder, by sliding along beneath the mouth of the clay pipe, pushes the finished brick onto an endless belt which removes them. As soon as the charging box has reached its position above the mold the bottom plates drop at once, the molds are filled with the powder, and the box removes any excess of the clay; thereupon the plungers again are lowered and the motions repeated.

In order to estimate the advantages and disadvantages of the process described, there must be considered also the question of economy, as well as the possibility of introducing these methods elsewhere; it is likewise necessary that we consider the conditions under which this industry has arisen. There is to be considered that the raw material of this district, as a rule, does not possess the plasticity which is required for the making of good brick in the ordinary way, and a powerful pressure is necessary in the molding of the bricks. It is now evident that such an intimate contact of the clay particles as we find in the ordinary method of soaking cannot be produced by even the highest pressure. This defect due to the method involved must be counterbalanced by very hard burning in order that the bricks may become sufficiently durable. On the other hand, after the necessary condition of hard burning has been fulfilled, the bricks possess great, undeniable advantages. The shape is more perfect and uniform than can be obtained in any other way, and the bricks possess a toughness and a resisting power to pressure and abrasion which is true only for the very best bricks. These bricks are sold, as a rule, at between 24 and 30 shillings per thousand in the size mentioned above.

The Manufacture of Brick from Dry Clay Dust

OTTO HENSEL, TRANSLATOR

The preceding essay describes a process of making bricks that has come into general practice in central England, and which consists in the application of a powerful pressure on powdered, almost dry clay to form the bricks. In returning to the subject I do not intend to repeat a description of the mechanical operations, but have in view rather a discussion of its features, to point out its rationale, as it were, to investigate from what necessities this process, entirely strange to us, has sprung and whether the same considerations that prompted the English brickmaker to abandon his old established methods, might also apply with us.

Though attempts have been made with us by modifications in the processes of manufacture, to bring under control such properties of the material which make the work of the brickmaker exceptionally difficult, or cause expense and losses in the partly or wholly finished products, it must still be admitted that on the whole, with a few exceptions, these attempts must be considered failures. Partly from this need, partly from the desire to do away with the imperfections of manual labor, or to become independent of it, have originated all machines employed in brickmaking; how in many instances they do not meet the requirements that can properly be demanded of them, I hardly need to recite. Particularly in the direction followed by the British brickmaking industry for more than a decade have the attempts made in Germany failed completely. There hardly exists today in Germany a plant where bricks are made of dry or almost dry clay powder, although it has been tried in many localities. The explanation for this want of success is to be sought not alone in the more limited circumstances, materially and intellectually, of the German industry as compared with those of the English—circumstances that continued to exist up to the present time, and which are a favorite apology for the low grade o the former as compared with the latter; the reasons are to be found rather in the limited intelligence of the producer and the low requirements for artificial building material on the part of the consumer. In order to avoid the difficulties that are met in reducing the material to a homogeneous mass so necessary to successful molding and burning, and ill-advisedly to save expenses, it was thought permissible to omit this preparation or to carry it on only to a degree necessary to get out an oblong block of burnt clay and not a tough brick capable of enduring weathering. That they assiduously fostered the notion, and do so still, that their machines were capable of molding brick very cheaply without any preliminary preparation, we may forgive the manufacturers of machines, but not those who from the daily handling of their raw material ought to know its properties well enough, and yet were duped by such worthless claims.

The visitor of English brick manufacturing plants will at once be struck by the contrast in the utilization of machinery in lieu of human labor as compared with us. Such are the machines for preparing and mixing the material, and their more extended employment is particularly prominent there, while with us these frequently occupy a too subordinate place or excel by their poor work.

While in Germany in the process of manufacturing brick from clay-dust the endeavor was to save as much power as possible and to compress the material in quite a raw state, as cannot otherwise be expected, where no machinery is employed in the reduction and mixing, we find in England a correct appreciation of its necessity, such a thorough preparation of the clay as may serve us indeed for a lesson.

To be sure, a material is extensively made into brick in England that from the current conception of our brickmakers would be declared absolutely unfit, while there it produces face-brick. That this is possible with a material so abnormal in its properties as understood in our practice, is all due to its careful reduction. It may even be supposed that the present process has been developed from the scarcity of such a raw material as could be worked by the old established methods; after the advantages of the process had been recognized, it was in turn employed for such plastic materials whose properties would have permitted their working in the plastic state by the old methods.

The raw material for the industry discussed is, in most cases, a shale of the carboniferous formation. It is a clay that will not become plastic with water and will only cohere at all if finely powdered and in contact with water for a long time. Weathering would indeed make it plastic, but the process operates so slowly that it will not furnish the material for manufacture on a large scale. Furthermore, the British climate is such as to raise doubts regarding the success of a proper weathering process. For the ordinary plastic clays also weathering is not commonly utilized. The winters are not cold enough to cause a deep and effective freezing through of the clay gathered in fall, and the summers too damp to cause a proper disintegration by changes in the weather; hence, mechanical powers here again have to do work that nature does more or less successfully in other regions.

In this way the necessity of a more extended application of machinery for the preparation of the material may be explained. If one further considers how much cheaper nature furnishes her aids, even though they are not entirely without expense, than it is possible to employ mechanical aids, the necessity for these may well be considered even greater than is commonly supposed.

We observe that the materials are such in the first place as are, to a high degree, devoid of plasticity, or as oppose such a resistance to their change into the plastic state, that the utilization of this valuable property of clays had to be renounced from the start; conforming to these changed conditions a treatment absolutely divergent from the ordinary is required.

The object of making the material homogeneous cannot be accomplished here by working it over with the addition of water, but a reduction to the form of powder is requisite in order to insure the necessary mobility of the particles. It is obvious that the reduction to powder can only proceed successfully with material of sufficient dryness, but the difficulties are not as great as we are apt to imagine. Of the two machines principally employed in this operation, the dry pan and the centrifugal disintegrator, differing in their mode of action, the choice depends on the properties of the material. The dry pan with its crushing surfaces cannot pulverize a fat plastic clay unless it has become almost air-dry at least, while it will easily accomplish the object with shale and lean clay and similar less cohesive substances even when quite moist; the disintegrator which pulverizes by subjecting the material moving freely in air, to a rapid succession of blows, will accomplish its object even with fat clays when they are as wet as they come from drained clay-pits.

All lamellar structure inherent in clays, due to sedimentation from water, and greatly resisting a uniform soaking and mixing, especially when silty particles alternate with clayey, is most completely destroyed by this pulverization. That thus a more effective homogeneity than by customary means is produced, is not the only practical advantage. A second one that cannot be valued too highly is the ready removal of impurities, roots, rocks and lime pebbles by the subsequent screening. This problem is still unsolved for large production by the plastic process. Because of these advantages, the method has been adopted by those branches of the industry that are naturally obliged to work clay in the plastic state, as in the production of sewer pipe, gas retorts, and fire-brick in general.

If this pulverized clay is to be molded into brick by powerful pressure, drawbacks to the production of a faultless product spring up, and they can be only obviated by observing certain precautions in the operations. In the plastic processes which effect the bonding of the smallest particles by a wet movable agent, the degree of plasticity of the softened clay is of great influence on the toughness of the product not only in the dried, but also in the burned state. In the process under consideration the complete absence of plasticity entails difficulties as the powerful pressure has to accomplish a cohesion of the finest particles analogous to that produced in other ways by the admixed water. This pressure is almost entirely ineffective if the clay powder is completely dry. Its effect must be assisted by a small content of water in the clay, just sufficient to insure a cohesion of the clay particles without hindering fine pulverization. The clay must contain an amount of moisture just perceptible to the senses, so that it balls under pressure, but cannot be kneaded. Nevertheless it seems as if the most powerful pressure will not give the strong bond produced by the plastic process. It is less apparent in the dried than in the underburned or soft-burned brick, for these are more easily destroyed by weathering than other kinds, and crumble under its influence to innumerable fine clay particles.

It is, therefore, further necessary to induce a cementing of the particles by a vitrification more or less complete in the burning operation, in order to insure proper cohesion. This result, ordinarily connected with some difficulties, can all the more safely be attained here since the molding has produced so great a density that shrinkage in the drying and burning is reduced to a minimum or is nothing; a warping by partial fusion is here much less to be apprehended than in all products shaped in the wet state and therefore initially full of pores.

The bricks pressed from clay powder require, therefore, a decidedly harder burn than is customary, if they are to be considered safe in regard to disintegration by weathering, but they nevertheless possess such perfection of shape, such smoothness and finish of the faces that they are the equal of any other product for the same uses; such perfection is hardly attained by other products. What makes this process, in addition to greatest regularity of shape, particularly desirable is the circumstance that the raw bricks directly from the press are so firm that handling will not indent them, and they can immediately be set in the kiln. Hence, an expensive drying apparatus can be dispensed with, and production is independent of the weather.

This probably constitutes the greatest advantage of the process, and will be appreciated by those handling a material that requires the greatest care in drying, and where the weather may imperil the result of all preceding labors; besides, there is no difference worth noting between production in summer and in winter. Whoever has noted how little space and labor are required in it, will involuntarily give this process the preference, though its defects cannot be gainsaid.

It might be said that firing of the ware while not quite as dry as air-dried bricks are, would be detrimental to the color, and thus make the advantages illusory to a greater or less extent. Nevertheless, it appears that with careful and slow water-smoking these difficulties can be overcome entirely. At least in several places where I had the opportunity to make observations, all difficulties in this direction that had originally existed had been overcome even with the continuous kiln from which we are wont to hear complaints of this sort. It may also be possible that the surface of the brick coming smooth, as if polished, from the steel-lined press mold, may have a favorable influence on the prevention of scumming. It must furthermore be stated here, that water-smoking of such bricks in the continuous kiln is always done with three dampers—a luxury that we in Germany do not consider permissible, and rather than go to so much trouble we prefer not to employ this kind of kiln for face-brick.

I desire again to call attention to this subject, not in order to recommend the process as a universal expedient in model brickmaking, but there is in Germany, like in England, plenty of material whose properties would make this process seem desirable, such as needs a separation of foreign matter which can be removed in the powdered state far better than in any other way, or such possessing too little plasticity or is so silty that it gives trouble in the mixing and molding, and lastly, such as shows abnormal shrinkage and is so sensitive to the effects of air and heat that its plasticity is but an obstacle to its working. I am of the opinion that a trial with such materials might furnish as notable results as have been accomplished in England, and it is rather worth while to keep this matter in mind.

The Manufacture of Black Vitrified Brick

OTTO HENSEL, TRANSLATOR

The manufacture of black vitrified bricks is one branch of the English brick industry, which has become very important in regard to brick architecture, though in Germany it appears to be entirely unknown thus far. The desire to employ these black bricks is spreading among us. Like the English architect, the German builder requires a black material to produce certain contrasts; but the material which the brickmaker furnishes for the purpose, differs so much in the two countries that it is well worth the trouble to examine the difference more closely and see if anything of value can be drawn from the English process.

Where black bricks are required for architectural ornament with us they are made by boiling ordinary face-brick in coal-tar. These bricks are no doubt improved in weathering qualities by the tar, but as dust soon collects on them they present an unsightly appearance; the original intense, somewhat glossy black in time passes into a disagreeably dead color—a gray. Many such tar-coated bricks are also to be seen in England, as this method is cheap; but in the better class of brick structures their use is excluded and they are replaced by a material that is incomparably finer and more durable. Our medieval structures extensively employ brick coated with a black lead glaze for the same effect, but the glittering surfaces of glaze offend the eye. As regards appearance the English products stand midway between the two.

The reader may recall the process of blue-smoking employed in the manufacture of black roofing tiles and brick and described in an account of the Belgian clay-working industry. A similar process is again met in English brickmaking, save that the effect of the dark color is enhanced by a kind of glaze possessing a matt luster, not to be confounded with the appearance of our glossy lead glazes.

The process for the production of the brick in question, styled "blue Staffordshire bricks," or "iron bricks," from their appearance and hardness, has its home in the center of the Staffordshire potteries, and in the south, in Bishops-Waltham not far from Southampton. The clay used is a ferruginous but rather refractory clay; the bricks produced from it approach in appearance closest those known in the Berlin market as Rathenow bricks, or those that are made from a clay originating from the weathering of the red carboniferous sandstone in the Saarbrücken coal basin. The clay for the brick is generally well prepared, usually by slumming. To produce a denser and more finished surface the better grades of brick are always repressed. Burning is carried on to vitrification either in the ordinary Staffordshire kilns previously described or in smaller ones similar to them, of round shape about 3.5 meters in diameter and 2.5 meters high, arched over, and fitted with six fire-boxes distributed around the circumference, and four to six small chimneys set on the semicircular crown for the exit of fire-gases. The bricks are set in them in such a manner that six flues are spared out, starting from the fire-boxes and meeting in the center in a vertical flue, and the faces which are intended to become black are left exposed in the setting. Thus for building purposes the bricks are set flat, for paving on edge, always so that those faces laid outward in the construction are left uncovered in the kiln.

When the heat in the kiln has risen so high that the bricks have passed into the vitrified state, several shovels of salt are thrown into every flue. In the intense heat the salt vaporizes at once and covers the exposed faces of the brick with a very thin hard glaze. At the same time a fresh charge of coal is supplied, and before the coal is completely ignited the fire-doors and chimneys are tightly closed and daubed up.

The smoke thus produced has an effect similar to that in the blue-smoking of the Belgian roofing-tiles with alder wood, though it is less intense. A blackening of the clay to the depth of several millimeters due to the reduction of the iron takes place, this action is augmented by the fluxes from the salt fumes that are filling the kiln, and a very dense and hard coating, dull glazed, and of the appearance of graphite, is produced on the faces of the bricks, thus creating a perfectly weather-proof exterior. This process is employed with brick not for the sake of the color effect alone, but also on the most extensive scale for those products where the first consideration is resistance to weathering influences and mechanical abrasion, such as roofing and floor tiles.

The Nassau Stoneware District

OTTO HENSEL, TRANSLATOR

A half dozen miles from Coblenz, and on the ridges of the Westerwald sloping toward the Rhine, we find an industrial district of the highest importance to us; in spite of its geographical seclusion it may be familiar, at least by name, through the medium of literary journals to persons residing at a greater dis tance. The many peculiarities exhibited by this district, its industry and its inhabitants, have repeatedly furnished material for descriptive and character sketches to publications of a literary nature; in approaching the same subject to-day we shall treat only of its industrial life and the methods of work employed; our purpose is only that of instruction.

In this district, whose chief towns are Höhr and Grenzhausen, an entensive stoneware industry has flourished for centuries due to the presence of excellent plastic and quite refractory clays; as early as the fifteenth century Coblenz stoneware was an imporant trade article in the large centers of commerce. Its old pottery, mostly jugs and pitchers that we frequently come across in museums and collections, and known in part under the appellation of "Flemish jugs," which general term includes products from various localities along the Rhine, are in respect to body the same as at present, though the decoration has materially changed, but not with credit to the present age. The old jugs and pitchers largely have their surface richly decorated with traceries, mostly foliage and vines by excision or in relief, arranged to form panels in which are represented scenes of the hunt, coats of arms, biblical or knightly subjects; the pleasing pearl-gray of the body is set off by a coloring of the ornament or of the background with a splendid blue or reddish brown, which to-day seems impossible of reproduction, or with enamels in various colors.

To-day when the tendency in all departments of industry as well as in pottery is towards production on a large scale and at the lowest possible prices, but to neglect the demands of mankind for beauty of form and decoration, the products of former centuries may still serve as models, in spite of our more refined taste and greater technical aids.

We must not gainsay to ourselves that herein lies the reason for the more backward state of the German as against the English and French pottery industries: since the inception of their development in medieval times, these have been steadily advancing, influenced indeed to a large extent by foreign countries, the French by Italy, the English by the German art pottery, while the German industry declined; and since the turn to a more flourishing state, which happily can be noticed for some time, it cannot meet the competition of other countries and of the more advanced products of the home industry, porcelain and white ware. In their endeavor to utilize all productions of art, especially sculpture and painting, as far as is possible in clay, also in the lower branches of pottery, foreign countries have arrived at grand results, and there those branches occupy a different and higher rank in relation to porcelain than is the case in Germany, and yet in spite of, or because of, this reason, they became large industries. If the German pottery industry desires to manufacture cheaply and on a large scale, it can do so to advantage in sewer-pipe and mineral water bottles, where decoration would be wasted.

To return to our subject and gain an idea of the extent of the stoneware industry in the locality under discussion, let us consult a pamphlet, compiled from official statistics, which describes the traffic of the district and is designed to prove what a profitable investment the construction of a railroad, for the want of which the country evidently suffers, would prove.

In the largest town, Höhr, there are thirty-four stoneware (bottles for mineral water, beer mugs and water pitchers) and six sewer-pipe works, four factories producing clay pipes, and one for better grades of stoneware and terra cotta; they employ 400 workmen, and produce 140,000 cwt. of stoneware and sewer pipe, 25,000 cwt. clay pipes and 150 cwt. artificial grindstones. (The German hundredweight is equal to about 110 American pounds).

Grenzhausen, the next in size, contains thirty-eight factories, that furnish kitchen and table utensils of all sorts, sewer pipe, jugs and clay pipes. With 150 laborers, in addition to the members of the potters' families, the production runs up to 50,000 cwt. of stoneware, 90 cwt. of pipes, and 1,200 cwt. of artificial grindstones.

Hilgert produces 20,000 cwt. of stoneware and 6,000 cwt. of pipes in ten factories. Baumbach, with eleven factories, produced 2,100,000 bottles for mineral water in 1871. In Ransbach the production amounted to 600,000 jugs and about 4,000 cwt. of stoneware from eleven "jug" and three "pot bakers." Werges figures in this list with 25,000 cwt. of jugs, Hunsdorf with 800 cwt. of pipes, Mogendorf with 66,000 cwt. and Hillscheid with 40,000 cwt. of stoneware.

The total foots up to 451,000 cwt. of stoneware, pots and sewer pipe, and 31,890 cwt. of clay pipes; in addition 523,000 pounds of the raw clay, which is found mainly near Grenzhausen, at Wirges, Ebernhahn, Dernbach, is shipped.

It will be seen that the quantity of clayware produced here is not inconsiderable, even if the production is distributed among a very large number of smaller establishments. The stranger visiting the district is indeed peculiarly impressed, and even those who are familiar with pottery districts find it strange, to see a potter at work in almost every house, in yards and gardens, here a kiln, there a horse-power machine, and at first glance he wonders how these mountains of jugs and pots are to be disposed of. But these potters are a hustling people that know how to sell their goods in distant parts, the mugs in beer-drinking Bavaria, the clay pipes in Holland and to distant markets across seas.

The clay used is an exceedingly plastic and uniform pipe clay of a purity and homogeneity rarely met naturally, and is obtained close at hand, as mentioned. Near Grenzhausen the clay is overlaid by thick beds of loam and red clay and is mined in the crudest manner from a shaft. A circular shaft is sunk through the overlying strata, usually 10 to 13 feet deep, and is lined with wooden hoops; then in digging through the clay, the shaft is gradually made wider, hollowed out as much as the firmness of the wall permits, giving the appearance of an inverted funnel; the clay is drawn up in tubs with a windlass.

In this manner the shafts are continued to a depth of about 40 to 50 feet, and in the widest portion below attain a diameter of from 26 to 33 feet. When further excavation on the sides becomes unsafe, the shaft is abandoned and another one sunk close by in the same manner. It is plain that a systematic working of the clay deposit in this way is impossible, and as the pits sooner or later all cave in, future generations will find it extremely hard to introduce a rational system of mining, especially if the consumption should increase, which will certainly take place, owing to the excellent quality of the clay. But here, like elsewhere in our country, where the class of small manufacturers clings stubbornly to traditional customs, any change is opposed; in this locality this state of affairs, which in many other respects is noted to be peculiar, may be due to the organization of the craft, for here the potters of each place belong to a trades union of medieval pattern and origin, which union mines the clay for its members. This institution, though an impediment to progress, has remained to the present day, the location of the district outside of the highways of commerce being favorable to its existence; there is hope that it will fall and be replaced by an association more in accordance with the conditions of the present, giving freedom of action to the individual, as soon as the much-needed railroad has been constructed and has opened communication with the outside world. The clay is spaded in quite regular oblong blocks weighing about six to eight pounds, and is partly stored under roof and dried by the potters, partly sent to the Rhine to be used by other manufacturers of claywares and fire-clay goods.

The clay is so homogeneous that formerly it was thought unnecessary to prepare it with the care required elsewhere; it was thought sufficient to soak it in water and work it by treading with the feet. To-day pug-mills have replaced this manipulation and do better work. The kind commonly in use for the last ten years consists of a tub of sheet iron on top 20 inches wide, 5 feet high and growing narrower from top to bottom, with a square aperture of 5 inches at the bottom. Its vertical tempering shaft, provided with knives set at an angle, passes through a vaulted floor above and is revolved by a horse or ox walking in a circle. The place containing the pug-mill, thus converted into a covered room, serves also as a store-room for the clay and contains the troughs in which the clay is soaked with water. The clay passing freely from the bottom of the mill on to a smooth slab of rock or iron is cut by a wire into lengths of about 20 inches and stored till used.

Compared with the variety in shape and use of the ware made in other pottery districts, the classes of products made here as regards composition are but few; the clay is worked up without any admixtures, except in the manufacture of grindstones, where fluxes and abrading materials are mixed with it; it burns to a very hard light gray or white body with a sharp fracture like porcelain, but so brittle that the production of ware which is subjected to heating, like cooking utensils, is excluded. With the exception of the clay pipes fired at lower heat, whose decorative traceries are sometimes set off by enamels and transparent glazes, all wares are salt-glazed.

Different branches of the industry predominate in the separate places, as the composition of the clay at hand is found better adapted to one or the other. For instance, in Höhr it is the production of sewer pipe, vessels for chemical factories and for the shipping of caustic substances; in Grenzhausen that of bottles for mineral water and the so-called whiteware, which term designates a very popular ware not brownish like the rest, but of a pearl-gray color, and mostly decorated by excision and coloring with cobalt-blue; these are mostly water jars, beer mugs and smaller pots. All products are represented more or less in every place.

In most potteries the turning does not offer anything worthy of note; the pulley of the wheel is located beneath the floor in a round recess; at present the wheels are never turned by the foot of the turner. The vertical axle running in a steel bearing now carries an iron wheel, about 20 inches below the disk which, before the lump of clay is put on, is given several whirls by means of a hollow bar inserted in one of the spokes; only in one case was another construction observed, turned by foot-power and using belt transmission.

Sewer pipe is made on presses which expel the clay in an unbroken stream and are operated by hand and in one instance by steam power. Presses for pipes of the smaller diameters force the cylinder of clay downward, and the collars cut from pipes of larger diameter, are stuck on afterward. For larger pipes, say 6 inches and upward, the pressing proceeds in the reverse direction, that is, upward, and the collars are pressed on in the same operation. The press consists of an iron cylinder with a piston inside, moved upward by a heavy screw, and is filled with clay. The top is closed by a plate with an aperture in the center corresponding to the external diameter of the pipe to be pressed; the opening is surrounded by a rim whose inside dimensions correspond to the external width and height of the socket. A round iron disk is accurately centered in the hole on top so as to leave a ring-like aperture corresponding to the thickness of the walls of the pipe; the plate is held in place by an iron rod in the cylinder and passes through the piston. In the pressing, a length of pipe of about 4 inches is first forced out, widened and pressed with the hand against the rim forming the socket. An oiled block of wood corresponding to the inside of the socket is now laid on and the socket die firmly pressed down by a screw fastened to a bow. On removal of the screw and block, the pipe is pressed out to its full length, cut off, a tin tube inserted to prevent loss in shape during handling, and is placed aside for preliminary drying. Made in this manner, the pipes do not have the perfect exterior required and, after the clay has become leather-hard, they must be trued up. For this purpose they are placed on a wooden cylinder and put on the lathe, where they are smoothed and grooves cut in the two ends to afford a better hold for the cement. Very large pipes, 40 inches and over, are laboriously made in several parts on the wheel and pieced together.

The burning is the most interesting part of the entire process, not that any especially practical features are practiced or that economy is striven after, but, on the contrary, because appliances are here retained which might be styled antediluvian, and since individual buyers strive with a zeal worthy of a better cause to raise prices for fuel by overbidding where they might gain by union and cooperative purchases.

The kilns are 10 by 13 feet long, about 5 feet wide, and 6 feet high, and covered by an oval crown. On one end below the kiln floor the fire-boxes are arranged provided with grates on which in the first part of the burn coal is always used and later on wood. The wicket for setting is in the other end. Four flues, 6 inches wide and 10 inches deep, extending from the fire-box to the opposite end, are cut out in the kiln floor and are loosely covered over with tiles of burned clay, about 2 inches thick and 8 inches long, thus permitting the fire to travel under the floor to the rear end. The walls are constructed of stone, lined with brick of a sandy and quite refractory nature, and are daubed on the inside with a half-inch layer of fire-clay mixed with straw and renewed from time to time, for protection against the fire, and especially the salt fumes.

On the two long sides near the top there is a row of round holes 8 inches in diameter and about 24 inches apart; these branch off at the outside into two openings, one of which ordinarily kept closed by a fire-brick slab, is on the side and is intended for introducing the salt for glazing; the other opening on the top platform of the kiln discharges the fire-gases, and is partly covered by a slab as is found necessary. The ware having been set with the aid of wads of clay, pottery pins and corks, so as to stand as free as possible, firing is begun and is gradually raised till white heat is visible. When the heat is considered right and the proper settling has taken place, trials are drawn to see whether the sherd has become sufficiently dense and vitrified; if this is the case, salting is begun. A very vigorous fire is maintained toward the end to counteract the lowering of the temperature by the vaporization of the salt, 100 to 200 pounds, according to the size of the kiln, fed with iron spoons through the holes mentioned. The salt glaze covers the surface of the ware very uniformly with a very thin but glossy and hard layer of glaze, for the fumes immediately penetrate the entire interior; ordinarily the glaze will be of a yellowish or brownish color, but if the precaution is taken to burn off with a large excess of air and to feed the salt in two charges at half an hour's interval and less at a time, a fine pearl-gray is obtained. After salting, the fireplaces are closed, the holes in the crown covered up, and the kiln left to cool. There being no stacks, the kilns represent but an unimperfect burning device and send vast amounts of fuel as smoke in the air.

From this short description it will be seen, that the industry of the district stands in need of many changes, if it desires to enter into competition with those of foreign countries, particularly those of Lorraine and England; the way for improvement has been smoothed by the recognition that changes in the mode of production are necessary, and by an active zeal that is observed to utilize the natural resources to better advantage. Four manufacturers of Höhr have combined to build a down-draft kiln at common expense, and the results obtained from it have so far been satisfactory; it is to be hoped that they will enter into other experiments, carried out mutually, that will finally evolve the type of kiln most suited to the properties of the clay. Then the industry must not rest with the production of the present varieties of articles; the fine qualities of the clay, its refractoriness, extraordinary plasticity, purity and whiteness justify the assurance that with the aid of other materials, such as quartz, spar, bone-ash, lime, etc., and by pressing all expedients of science and technology into the service, more valuable products can be manufactured; and if the German industry follows the example set by the French, and especially the English potters, to abandon the production of cheaper ware on a large scale, replacing it by such, which by beauty in form and decoration better satisfies the esthetic taste, it will, because of the generally more favorable local conditions as compared with foreign countries, gain a victory over the latter at least in our own country.

We must not pass over in silence the fact that the ambition for improvement noticeable in the district is mainly originated and kept awake by an industrial association (whose moving spirit is Rev. Müller in Grenzhausen) which, with the aid of the central association in Wiesbaden, has sent out two intelligent potters at a salary, to gather experience in German factories and museums, and is preparing, by instructing them in the English language, two others to go to England as workmen to collect knowledge and to utilize it for the welfare of the whole. It has also, partly by purchases, partly by gifts of the central association and of the Royal Porcelain Factory at Berlin, come into possession of a model collection quite complete for a beginning, so as to be able to show the producer good models from other factories and countries.

II. Reports on the Vienna Exposition, 1873

PROFESSOR HEINRICH RIES, TRANSLATOR

VIENNA, May 15, 1873.

The general exposition at Vienna at which all nations of the globe came together in friendly competition was officially opened on the 1st of May, 1873. Some people may question whether the good derived from such world's expositions is equal to the amount of energy and trouble expended in these undertakings, especially since they come as often as every five years.

It is not my task to describe everything of interest which is exhibited at Vienna, for it would not be in the power of any man to go into a detailed study of everything to be seen on such an occasion, and I must therefore limit myself to such things as are of most interest to my readers, namely, the products of the ceramic industry.

Since all the exhibits are not yet set up, and it would not be possible to make an intelligent comparison of the products of different nations until they are all on exhibition, I must therefore confine myself for the present to special mention of certain individual exhibits. At the same time it is probably desirable to acquaint the prospective visitor with the general plan of the exposition, so that he may know the way and not lose any time when he comes to visit.

The exposition building lies in a great shady park, the Prater, the whole covering about 1,060,000 sq. meters. The exposition, therefore, occupies about twice as much space as the last one at Paris which covered only about 450,000 sq. meters.

For the sake of systematic arrangement the exhibition place is divided into four zones. The first, best reached through the main gate, contains a large park, in which are a number of pavilions and restaurants. The catalogue makes note of fifty-three single buildings which, in part, represent dwellings of the separate nations; in part they illustrate some human occupations.

The second zone, which adjoins the first, contains beside the industrial palace proper the art building and a number of representations of dwellings, altogether twenty buildings. Of these buildings the industrial hall deserves particular mention. It consists of a quadratic main structure, each side being 210 meters long, built in the richest Renaissance style; in the center there rises a great cupola. The latter is supported by thirty-eight pillars and bound together by a great iron ring; it has a diameter of 103 meters and a height of 79 meters. The main building is adjoined, on two sides, by two long halls, 360 meters long, 24 meters wide and 9 meters high. From these there branch off, at right angles, eight smaller galleries on each side. The main building with its rotunda is open to all nations; the main hall with its branches is occupied by the separate nations. In distributing the space the idea kept in mind was to arrange the nations in the order of their geographical position on going from east to west, thus at the west gate America is the first, while at the east gate the exposition ends with China and Japan. Germany, accordingly, is about in the middle, followed by Scandinavia, Belgium, Italy, Switzerland, France, Spain and Portugal, England and America; on the right side there follow Austria-Hungary, Russia, Turkey and Greece, and finally Africa and Asia.

The third zone occupies the space behind the industrial palace and contains a number of single exhibition buildings belonging to the different nations, which contain either the exhibits of great industrial institutions or collective exhibits of certain branches of industry for which space could not be found in the main buildings. This zone contains forty-five buildings.

The fourth zone includes the great machinery hall with its attached machine shops, boiler houses, and work-rooms of different nations, as well as certain special exhibits of large firms, including in all twenty-one buildings. The machinery hall has a length of 825 meters, and a width of 45 meters, and is divided into three aisles. In the middle aisle two lines of shafting run almost the entire length for the purpose of operating the different kinds of machinery. The arrangement of the exhibits is the same as in the other buildings.

The exhibits in each of the spaces occupied by the different countries are divided into twenty-six groups, so that one can tell from a glance at the exhibit what the main industries are in a particular country. These twenty-six groups are as follows:

I. Mining and metallurgy.
II. Agriculture and forestry, wine, fruit and horticulture.
III. Chemical industry.
IV. Food products.
V. Textile goods and clothing.
VI. Leather and rubber industry.
VII. Metal working.
VIII. Wood working.
IX. Stone, clay and glass industry.

X. Hardware.
XI. Paper-making.
XII. Graphic arts and industrial drawing.
XIII. Machinery and transportation.
XIV. Scientific instruments.
XV. Musical instruments.
XVI. Army exhibits.
XVII. Naval exhibits.
XVIII. Structural and civil engineering.
XIX. A citizen's dwelling, its arrangement and decoration.
XX. A peasant's house.
XXI. National domestic economy.
XXII. Exhibit showing the working of museums for artistic handicrafts.
XXIII. Religious art.
XXIV. The objects of art, art in early periods as shown by art patrons and collectors.
XXV. Sculptural art of the present.
XXVI. Educational exhibits.

From the above we can see the location of the ceramic exhibits. This would include group 9 of the individual national exhibits, which comprises glass, porcelain, stoneware, earthenware, terra cotta, and refractory products, as well as group 13 containing clay-working machinery, and group 18 which embraces structural materials of clay, cement, and lime. In addition to this we shall find a few things to interest us scattered through the other groups, as for instance, coloring materials among the chemical products, and art products in groups 22, 24, and 25.

VIENNA, May 28, 1873.

In my previous letters I have been complaining somewhat of the fact that it was not yet possible to obtain a complete idea of the ceramic industry at the exposition, because the exhibits are not all in place, and I must continue to complain. Much, however, has gone on in the last two weeks, and the pottery exhibits proper, can be looked upon as being complete, but it will be some days before all the different types of machines used in the ceramic industry will be set up.

I shall at first confine myself to the discussion of pottery in its various branches, and I shall begin with the English, because, on the one hand, it is the first to be seen on entering the west gate, on the other, because the English pottery is closely related to the German products, and hence is best suited to our tastes. In the artistic products of a people the national character is especially brought out, and on comparing our products with the English it is quite evident that we are not unworthy pupils of the English.

ENGLISH POTTERY INDUSTRY

The products of this nation are set up at the western end of the industrial building, and as a result of their richness in color and variety of shape they claim the admiration of all visitors. It is not possible to do justice to this exhibit in writing, and one has to inspect it personally in order to form a correct idea of it. It is impossible for me to go into details, and I must therefore content myself with pointing out the main character and with comparing it with the exhibits of other nations.

While the art, and especially the pottery industry in any country, usually shows a character in harmony with the national taste, which usually makes it recognizable at once, still the pottery of England as developed at the end of the last century must be said to show a more or less cosmopolitan character, because its traits have been borrowed more or less from all nations, and yet at the same time adopted in a more or less original way. We find reproduced here the elegant forms and classic decorations of the ancient Greek and Roman potters, and next to them the forms, colors, and monstrosities, which could only emanate from the fantastic brain of a Chinese or a Japanese, or again we see the strongly modeled lines of a Della Robbia faience next to the intricate spirals of the Renaissance, or the beautifully drawn lines of a Persian or Moorish wall tile followed by the fine and delicate lines of the artistic faience of Henry II and Palissy's Amphibians. The slender forms of old English silver services, the Rhenish drinking cups of the middle ages, the compressed forms of the Delft wares, in short, imitations of the products of all periods and all nations are to be seen before us here forming a bright mixture, and yet each one shows its English origin.

The Berlin and Meissen porcelain factories could perhaps have done more in overcoming the technical difficulties which the material presented, but in the productions of no other country is the principal character of the clay taken advantage of to such an extent as in England, for no other shows such a richness of strong forms, of full colors and such a manifold application of all technical aids.

If we now pass from the general character of the whole exhibit to a discussion of the work of individual exhibitors, we find again here that at first sight the products of even two neighboring factories show a variety in form and methods of decoration such as is hard to find in any other country where the same materials are used, and it is hard sometimes to determine why this is so.

The factory of Brown-Westhead, Moore & Co., at Hanley, Staffordshire, shows a rich output of earthenware and porcelain articles chiefly intended for table use. The decorations are largely filled-in print work, but there is at times some raised paste work, such as wreaths and some small decorations of the majolica type; there is also a large vase decorated in Wedgwood style, but which lacks the delicacy of true Wedgwood ware. Deserving of special mention are three dark blue, narrow-necked Etrurian vases with pâte-sure-pâte decoration of Grecian design, so that the frit applied over the dark glaze allows the latter to shine through it in thinner spots and produces a very pretty shading. A second exhibit by this same firm contains toilet sets which are either plain white, marbled blue and gray, or even richly painted and gilded.

Near-by the preceding exhibit is that of George Jones, in Stoke-on-Trent, which consists mostly of majolica vases for garden use, some of them of considerable value, concerning whose character I will speak of later. A second exhibit of the same firm in the north cross gallery consists mostly of table sets, which are chiefly plain white with printed and sometimes painted decoration; some are also decorated in a manner much used by English potters, namely, a shaded effect is produced by pressing the outlines of the pattern into the body and then covering these with a green transparent glaze so that the higher portion of the design being covered by but a thin layer of glaze allows the white color of the body to be seen, while the impressions having a deeper layer of glaze, appear much darker. The designs for this type of decoration are mostly leaves and vines, as these yield the most effective results. Handles and lips of vessels are formed in imitation of animals, such as birds, lizards, and snakes, whose natural colors are well imitated.

Among the most interesting exhibits as well as the most artistic and valuable there belong those of the Royal Porcelain Works at Worcester. The collection comprises a number of tea sets in Chinese shapes, glazed in blue and yellow, and decorated with impressed designs. Especially striking are some teapots of a cube-like shape, which in one corner have the head of a lizard while the handle is formed by the body and tail of the monster.

In addition we also see here finely modeled terra cotta busts and statuettes, with blue-glazed clothing and brownish skin, as well as some which are glazed in bright colors; there are, furthermore, porcelain services of remarkable thinness decorated in the most delicate manner with garlands of roses. Of special interest is a teacup made at this factory, which is in the form of a cup with three feet, which although very plain (being decorated only by a small relief medallion) is at the same time beautiful in its outlines. The otherwise smooth surfaces are gilded and covered with alternating beads of gold and white enamel, the rim of the cup being set with blue-enameled pearls. Several additional works of art of this type are plates and fruit dishes decorated in a similar way with strings of golden pearls which are gathered together into the form of vines and tendrils, attached to which, here and there, are little enameled drops resembling pearls.

A specialty of the Worcester porcelain works is the production of Parian ware, or ivory porcelain, a body, which, on account of the large addition of fluxes, possesses a much greater translucency than ordinary hard porcelain, but at the same time shows a yellowish tint so that it bears some resemblance to ivory. The body is made of a mixture of clay, feldspar, powdered flint, and bone-ash, and the articles in burning are packed in flint inside of saggars in order to prevent warping; the burning on of the glaze is done in a second fire which does not reach the same temperature as the first one, in order to prevent change of shape.

The shapes are mostly Chinese, and are covered with decorations of the same nature. Some of the forms are truly remarkable considering the difficulty offered by the body which is used. Among these is a little tea-pot of ovoid shape. It has double walls, the space between them being hollow. The inner shell forms the true wall of the pot, while the outer one is of extreme thinness, and decorated with vines and leaves which are cut out when the ware was in the green condition. No price was given for this work of art, but if it were placed on sale the great value of the laborious and expert work required in its production would have to be taken into consideration. Two additional pieces were a pair of vases about 0.5 meter in height, whose handles were formed by entwined snakes. The pieces colored in a magnificent blue and richly decorated with gold show on the body historical representations beautifully executed, apparently excised from the unburnt glaze coating.

Besides this there is a great amount of brightly glazed majolica decorated in relief, and also table sets with similar decoration.

The exhibit of Minton, of Stoke-on-Trent, is equally full of beautiful objects which show a still richer decoration and greater variety of form than the preceding exhibit. The chief objects are majolica for both garden and domestic use as well as for decorative purposes. One of the finest is a vase whose handle is formed by four chained warriors, while the cover shows Prometheus and the eagle on the rock as well as a shell-like water basin carried by two water nymphs. These majolicas which play such an important part in the product of every English pottery are made from a refractory clay and are decorated in either low or high relief according to the use to which they are to be put. For example, jardinières are decorated with vines or wreaths, or else the surface is made to represent interwoven branches; flat vessels are decorated with leaves, while drinking cups are ornamented with grape or hop leaves, or in some cases with symbolic animals. All of these ornaments which project above the surface of the vessel are decorated with harmonious colors and the large flat surfaces, as for instance the inner side of the object, are glazed with opaque tin glazes and the rough or ornamental parts with transparent, brilliant lead glazes, so that as a result of the running together of the glaze on the depressed portions and the color of the body shining through the glaze on the raised parts, a very effective shading is brought about.

This type of clayware shows the true character of the English products, and the style of decoration finds application on even the higher grades of clay products as porcelain and Parian ware. The prices range according to the size of the object, the fineness of the modeling, and I noticed individual pieces whose price ran as high as 300 florins. The Mintons have also exhibited a great series of majolica and other garden pieces which are decorated in different ways, as, for instance, those in which the designs of geometrical figures or plant wreaths are either pressed into the surface or the outlines marked with a knife, these appearing dark in color; by using a glaze, or by the application of a slip sometimes of a dark shade in contrast with a light one, or *vice versa*, or again, by engobing the entire surface and cutting the design through the slip, exposing the color of the body underneath, various other decorations are produced. Another style of decoration which is used only on flat surfaces and different kinds of tableware, especially the cheaper ones, is carried out by printing the design on the surface. This is done by first printing the design from a copper plate on to specially prepared thin paper, which is then applied to the surface of the ware and rubbed firmly on it. After moistening the paper and drawing it off the color impression is left on the surface of the ware and is burned in. These printed designs are sometimes filled out by painting, and retouched with muffle colors.

Of splendid appearance is a series of dishes whose ground color is olive-green on which are painted allegorical and mythical figures in Grecian style. The figures seem to stand out in relief owing to the fact that over the glaze there is a thin white layer of frit so applied that the dark ground shines through it in a manner similar to Wedgwood ware, but differs from the latter in that the whole surface shows a glazed appearance. Also worthy of notice are some imitations of Italian and French majolicas, and above all some copies of Henry II faience. The characteristic feature of this faience is that the designs are cut in a yellowish clay, the lines being so fine as to be scarcely noticeable to the naked eye, the depressions being filled with a colored clay, mostly brown or black. In addition to these types whose imitations have thus far been reproduced only by the Mintons, there are several other pieces such as a large clock case and several small vases and flask-shaped vessels.

Finally I must call attention to the beautifully decorated porcelain plates with humorous pictures of children and a number of plates with cupids and playing fairies surrounded by a cloud-like rose color effect. The latter especially are wonderfully beautiful and delicate, but at the same time very expensive, one plate alone, with an open-work, gilded border, costing 7 pounds sterling; it is, of course, the value of the painting which is here being paid for.

I think the above will give a fair idea of the richness of Minton's exhibit, and there remain only the exhibits of wall decorations to be mentioned.

Wall decorations are exhibited by two firms, namely, Minton, Hollins & Co., in Stoke, and Robert Taylor Minton, in Jenton, Staffordshire, who have also exhibited some fine tiles for flooring. The wall tiles are either flat, about 15 cm. square, with either Persian or Grecian patterns, so that when put together they show a repeating geometrical design of large dimensions, or in other cases the tiles carry a majolica decoration with relief ornamentation, the individual parts of the design being covered with glazes of different colors, and represent floral decorations. Part of the tiles are decorated with figures of Persian and Turkish designs sunk in, the sunken portions being covered with a differently colored transparent glaze or enamel than the relief decoration.

Finally, there are those in which a light burning clay seems to have been put over a dark body in the form of an engobe and the two then covered with a transparent glaze. There is also a large selection of encaustic tiles, in a variety of patterns. The perfection of the painted designs, the clear colors, and the brilliancy of the glazes as well as the contrast between bright surfaces and monochrome borders give to these products a most brilliant appearance. There is also a series of tiles in which the design covers a number of pieces as well as panels for mantel decoration, whose coloring is wonderfully executed.

The floor tiles are either made out of differently colored three-, four- and six-sided plates which are combined mosaic-like to form geometric figures, or else the tiles are unglazed hard-burned plates decorated in various patterns.

The firm of W. T. Copland & Sons, in London, and Stoke-on-Trent, has in addition to glassware and majolica of all sorts, an exhibit of earthenware and porcelain. Of special beauty are some white plates on which there are painted, in simple outline, butterflies and small birds resting lightly on flowers and grass; so natural are they that one is almost tempted to reach out and touch them. We should also mention a tea service with elliptical saucers in a similar simple but rich design.

The well-known firm of Josiah Wedgwood & Sons, in Etruria, Staffordshire, shows, besides a number of painted table services and majolicas, some Wedgwood ware so beautiful in form and decoration. The vessels on account of their shape are to be looked upon in part as reproductions of Greek vases, and in part only as show-pieces, and are decorated in the Wedgewood spirit. The relief designs, usually taken from Greek mythology, are applied in a white translucent body so that the colors of the objects, a rich corn-blue, bright olive-green, violet and black appear through this layer where it is thin. The modeling, following the style of the Etrurian vases, is wonderfully fine. The decorations, as well as the ground, are matt without any glaze, and the ground is covered with a white translucent engobe. Many small pieces, such as match boxes, cups, mugs, and medallions, are sold at prices which are very reasonable when the beauty of their decoration is taken into consideration.

Of no less interest than the ornamental pottery, the principal pieces of which I have described, are those wares of which domestic use is made, and which are especially represented by the salt-glazed products of the Lambreths of London. The firm of Jennings & Co. shows a number of glazed stoneware pipes and fixtures for bath-rooms, wash-stands, and closets, the products being well known over the entire continent of Europe on account of their high quality. The firm of Doulton & Co. shows in addition to the above a number of articles for industrial use, such as distillation retorts, condensing coils, stop-cocks up to 8 inches internal diameter, combustion tubes, etc.; also jugs, bottles and pots, boxes, and many other household objects which can be turned out on the wheel, and are apparently coated on the upper half with a thin slip which burns to a brown color and is covered with a hard shining glaze.

The firm of Doulton & Watt shows in addition to salt-glazed stoneware for structural work, also a line of domestic utensils which are prettily decorated in a very simple way. Its imitation is suggested to our stoneware industry of the Rhine and Lausitz district.

The objects are mostly drinking vessels, jugs and mugs, of Flemish design which are sometimes decorated with relief figures, but in most cases the designs are simply cut into the green clay, in plain outlines, the lines being filled in with blue, brown or black color; they are mostly animal, hunting or drinking scenes which are produced in this really beautiful style, and are far superior to the different and often distracting excision of flowers, leaves, and animals, which are to be seen on our native stoneware products, and which usually are the first artistic attempts of the younger members of our potters' families. I cannot say whether these tastily executed designs come from the hand of a skilled artist, since I could not find out anything about it; I do believe, however, that those of our own potters who devote their energy simply to the reduction of the cost of production could benefit themselves by the imitation of this kind of decoration, by having artistic designs cut out of very thin copper sheeting and using this as a stencil on the green ware by following the lines with a pencil.

Of building materials very little is shown in addition to some terra cotta by Doulton & Co., some door-arches and an elephant. The firms of Wood & Ivory, in West Bromwich, Staffordshire, and Doulton & Co., in Lambreth, exhibit dry-pressed bricks which are covered with a bright glaze whose method of manufacture has been described by me on an earlier occasion. The cement works of J. C. Johnson & Co., in London, show a large, concrete block ground on one side made up of one part cement and ten parts of differently colored marble fragments so that the polished surface has an appearance not unlike marble. Finally, there are some samples of an apparently very hard cement made for the purpose of cementing metals and another used in laying roofing slate.

INDIAN CLAYWARES

Close to the English exhibits are those of the English colonies of which, however, only India is represented by ceramic products. The technical aids which the Indian potter has must indeed be very limited, for he has nothing more than the wheel, a modeling stick and his hands; nevertheless the products of his work are extremely interesting, and truly extraordinary considering the limited means at his command. The hollow wares, long-necked bottles, urns, bowls, plates, and, finally, vase-shaped show pieces are all turned free-hand on the wheel and subsequently decorated in various ways. Some objects are entirely red, as the urn-shaped wares which apparently are simply used for the preservation of dry materials, and the porous cooling jugs which are in use in all warm countries, while others are decorated by dusting mica flakes over the surface or cutting in the lines of the design. In some of the glazed pieces we also find underglaze painting. The colors which are used in the glaze are different shades of those which can be produced by the use of tin, iron, copper, manganese, and cobalt; in other words, white, yellow, green, violet, and blue, which are then applied either to decorate the whole surface, or to bring out individual lines of the decoration. We find, for instance, jugs whose white glaze is encircled with bands of blue; there is also a series of wall tile, white enameled, and decorated with blue and green leaves which on the wall form a symmetrical pattern; there are also other wares under whose glaze there are scratched various designs such as stars and foliage; or sometimes the design is painted under the glaze with a white clay and these patterns are usually executed with much more care than similar ones seen at our German common pottery fairs. Of special interest is the terra cotta for decorating buildings, of which there is not only a rich variety, but also photographs showing their position in the great Indian temples. In addition to the glazed wall tiles covered with Persian patterns, which I have already referred to, there are others which are ornamented with open designs, also glazed. The unglazed terra cotta, such as capitals and friezes, whose decoration consists of the distorted faces of Indian gods surrounded by lotus flowers and delicately wound vines, are, like all the claywares, formed free-hand, and together with the other Indian pottery deserve great credit for the beauty and uniformity of the lines and could well serve as a pattern for our own industry which has at its command much greater technical aids. In addition to the clay products the Indian government has sent several sculptured window decorations cut out of marble and sandstone.

THE FRENCH CLAY INDUSTRY

This division of the exposition is no less educational in its character than the English, but it is unfortunately not as complete, for the lower grades of pottery and faience are not represented at all. It is well-known that the French pottery industry has taken its early examples from that great era of art which in the fifteenth century spread outwards from Florence, Pesaro Gubbio and Faenza in Italy, and that since that time the celebrated potteries at different localities in France, as at Nevers, Rouen, Limoges, have been founded in which the French pottery industry has developed simultaneously with the English. In the French pottery the richness of form which was so characteristic of the English products tends to give way to painting on flat surfaces. While in the English decoration the design is carried out in broad strong plastic lines which stand out from the background, and by their relief produce the proper variations in light and shade, in the French the smallest details of ornamentation are executed with the brush, and we have thus a fineness and detail of design which can be seen elsewhere only in the Italian mezza-majolicas. As a result of this we see sometimes in the French products an excess of color decoration, so that the latter becomes of primary importance and the shape occupies a subordinate position in the decorative effect. While in the older Italian majolicas, which are to be looked upon as the starting point of the French pottery industry, there was a separation of the different parts of an object, such as the bottom and edge of the plate, each of which had special ornamentation, when we come to the French pottery this differentiation has been largely forgotten, and the design is simply carried from one portion over into the next, or else the shape is modified so that the different parts of the vessel lose their individuality, and the latter simply becomes a placque or a shell which merely serves the purpose of a background upon which to paint. The result of this is that the form and painting of the French ceramic artists possesses a certain indefinable individuality which gives to it a high degree of elegance known only to French wares. In addition to these objects, which have a specifically French character, there are exhibited others which are in imitation of Oriental, Chinese, and English styles, and which I will mention in describing the individual exhibits.

The firm of Geoffroy & Co., in Gien Loiret, has an exhibition of faience which consists partly of domestic articles, but chiefly of ornamental wares of all kinds, of which there is a great variety. They are mostly white faience with a white body and colorless glaze under which the decoration is applied in cobalt-blue after the manner of the faience of Rouen, the design being very delicate leaves and vines; there is also a large number of articles of ordinary faience which is covered with a white tin glaze, and which in form and decoration imitate in part the old Delft ware, or in part the older styles of Italian faience. The painting in Rococo style, or in Italian Renaissance, is applied with great care and delicacy upon the soft powdery glaze before it is burned, and therefore requires a firm and skilled hand for each line; after once applied it cannot be changed; as in the case of the Italian faiences, of which these are imitations, there is very little change in color; it is mostly blue, green, and brownish yellow in different shades, and is applied on a white ground. The collection of this exhibitor is very rich, and finds appreciative customers among the visitors to the exposition.

The exhibit of Jules Houry, of Paris, is no less interesting. It is an exhibit of domestic ware in which the skill of the potter is used to support the ornamentation. The exhibit contains slabs and rims for tables, panels for sideboard doors, work-boxes, flower-holders, aquariums, and mantel-pieces. These articles are made of bronze, carved wood and other materials, which serve the purpose of framing the clay tiles. The technology of these artistic things is quite unique. The plates or panels are apparently white faience or biscuit, on which the ornamentations are in harmony with the use to which the article is to be put, and consist of figures pressed to form a low relief. These relief decorations are covered with a translucent, rich blue, but slightly transparent glaze so that there is a proper distribution of light and shade which is still more strongly brought out by the fact that on certain spots the glaze has been rubbed off partly before the burning, thereby allowing the color of the body to shine through.

The firm of Collinot, in Boulogne, exhibits a series of faience for decorative purposes, the style of which is strictly oriental. The exhibition pavilion of this firm is supported by columns, the whole structure being faience work, and illustrates the different constructive applications of the glazed wares from this factory quite well. The walls are decorated in part with tiles bearing Turkish patterns, which are unglazed characters and stand out boldly, while the ground is filled in with green enamel. Some of these tiles are joined together to form a large floral design. In these, as well as in several larger vases set up for exhibition, the outlines of the individual flowers, leaves, stems, etc., are emphasized by black lines which have been scratched into the ware, the areas bounded by these lines being covered by a thick enamel so that the different pieces stand out from the ground more or less in relief. The lines separating the different colors are filled in with a dull black glaze, which prevents the running together of the colors, and consequently we do not find the gradual merging of the colors, which we often observe in some wares, but which is not always desirable.

Of similar design, but richer in color, are the articles made by Parvillée, of Paris. The exhibit embraces a series of dishes, pitchers, and vases, of moderate dimensions, which are decorated over their entire surface with wonderfully fine incised Persian decorations. The enameled decoration is not confined to certain portions of the surface, as was the case with the wares of the previous exhibitor, but the intertwined and finely drawn patterns are completely covered with enamels showing rich colors and endless changes, and as the individual colors are separated from each other by extremely thin black lines, the result is that the enamel applications stand out in big drops and thereby increase the brightness of the design.

Next to the two exhibits just mentioned is that of Th. Deck, of Paris, which shows in addition to fine faience and faience decoration of plates (the latter consisting of life-size portraits), a great piece of wall decoration, in front of which there is a jardinière. The technique is here the same as in the preceding except that the Turkish and Persian designs have disappeared from the decorations.

Among the beautiful high-grade faience for domestic use are to be mentioned first the articles of H. Boulenger, in Choissy-Le-Roi, and Soupireau & Fournier; the last-mentioned firm shows floor and wall tiles with pressed or brightly glazed majolica decorations, and a large majolica stove whose panels are decorated with coats-of-arms and strings of fruit decorated in brilliant colors on a white background.

In the section occupied by Barbizet and Sergent, of Paris, we find a series of majolicas finished in the English style and faience in the manner of Palissy, all of the articles being decorated in natural colors with snakes, fishes, crabs, and worms, the decoration being applied either to domestic articles or ornamental pieces; none of these articles, however, can be said to come up to those of the English factories. It is also noticeable that there is a much greater running together of colors, than in the case of English wares, which is especially unpleasant as some of the neighboring shades do not harmonize.

The hard porcelain industry is represented by decorated domestic utensils, statuettes, vases, and busts, in biscuit, of which the first-mentioned are especially worthy of notice, owing to the wonderfully fine and rich decoration of the drapery on the figures. The firms exhibiting are Vion & Baury, and Thierry Poulin, both of Paris. The latter exhibits also ordinary domestic ware consisting of a white body and decorated by printing and painting.

Gosse, of Bayeux, has an exhibit of hard porcelain ware, especially ware for chemical purposes, such as digesting vessels, evaporating dishes, retorts and tubes, also porcelain kitchen ware, as well as ware decorated with a brown-slip glaze similar to the Bunzlau ware made in northern Germany. J. Brianchon, of Paris, shows porcelain and faience with iridescent metallic-luster glazes, in all colors, made according to a new process. I have not mentioned all the French exhibitors, but only those whose exhibits showed special technical prominence. There are exhibits not only in sections devoted to ceramic products proper, but also in other groups, such as the bronzes, illuminating apparatus, and art paintings on porcelain.

The tardiness in the placing of the different exhibits made it necessary for me in my earlier letters to restrict myself to an examination and study of those objects which were already placed. To-day it is possible to see the exposition in its entirety, and it is, therefore, practicable to make a comparison of the different countries in a systematic way; at the same time I reserve the privilege of discussing the products of the different countries individually as I have previously done. As, however, the different countries excel first in one direction and then in another, and as these different branches do not interest all of my readers equally it seems to me necessary to bring in the descriptions of those exhibits or groups which call for general interest; I shall therefore begin next a description of the brick machines, and conveying apparatus. I am prompted to do this since a large amount of material is available for study especially in the divisions of Germany and Austria-Hungary. Owing to poor arrangement the exhibits of interest to the ceramic technology are found in all sorts of corners, being distributed without any regard whatever for classification, and hence it is a difficult undertaking to obtain a general view and to select the products of high-grade establishments.

Brick Machines

The object of these machines in the brick industry is first to make the manufacturer independent of hand work; and second, to make a better and more salable product at less cost. Most of these machines used at the present time in our own country go but a short distance toward fulfilling the requirements mentioned. This fact is due not to careless workmanship nor to the difficulty of working the machine, but is to be found in the systems adopted. All of our German machines which work soft clay are built on the principle of forming the bricks by forcing the clay through a die by means of inclined knives set on a shaft, rolls, or other means, the clay issuing from this die in the form of a rectangular bar which is cut up into bricks. In bricks made in this manner we find most of the faults exhibited by machine-made bricks, which are brought about by the difference of density between the clay in the outer portion of the brick and that of the interior, these faults being more pronounced the stiffer the consistency of the clay when it is fed to the machine; less sensitive to these defects are the hollow wares made on this type of machine, such as hollow brick drain tiles, and roofing tiles, the reason for this being that greater care is usually exercised in the choice of the clay and its preparation.

Unfortunately we do not find among the German machines exhibited any decided improvement, although we observe that some steps have been taken to remove some of the defects now so often produced in bricks.

Among the exhibits at the Vienna exposition we find the widely known brick presses of Hertel, from Nienburg a. S., Schlickeysen, in Berlin, Schmerber Bros., of Jagolsheim, near Mühlhausen in Alsace, L. Henrici, of Vienna, and Louis Jäger, of Burtscheid, all of which work plastic clay. In the English division we find a machine made by D. Thos. S. Derham, in Leeds, and in the French division a hand-press of E. Pavey, in Château du Claveau. Roofing tile presses are exhibited by Schmerber Bros., and the same firm shows a large press for the manufacture of hollow bricks, pipe, and roofing tiles, while the firm of Edward Laeis, in Trier, exhibits a hand-press for making French roofing tile, and E. Page & Co., of Bedford, England, a press of the Whitehead system.

The well-known firm of Sachsenberg Bros., of Rossla, has unfortunately been unable to show any of its brick machines, owing to the lack of space. It is, however, represented by a large sewer pipe-press with pug mill and elevator.

Two new kinds of brick machines deserve the attention of brickmakers. Both inventions, the one by E. Pavy, Château du Claveau, France, the other by A. Freund, of Vienna, have the same object, namely, the reduction of the thickness of walls, because the bonding of one brick to another is not dependent upon the adhesion of the mortar alone, but a process of anchoring each stone to its neighbor adds additional strength to the masonry. The system of E. Pavy, which was patented in France, is supposed to be advantageous for those walls which are simply carried to a great height and do not have to support any outside load, or such that are to resist simply a pressure applied horizontally, as chimneys, towers, arches, water reservoirs, etc.

The bricks are given a preliminary shape, and are then repressed when partially dried in a hand press, the number of possible shapes and sizes being very large. A swallow-tail-shaped recess on one end of the brick adjoins a similar recess in the next brick, the recess in each brick being about 1 cm. deep. Into the double recess formed by the two adjoining recesses a double swallow-tail-shaped piece is inserted which is specially molded and burnt hard. In the case of circular walls, such as used in chimneys, Mr. Pavy claims that only one-third as many bricks are required as would be under ordinary conditions, while the stability of the structure is greatly increased. It is also possible to construct a double-walled chimney, the two portions being connected by cross ribs which are fastened to the bricks in the same way that the latter are to each other. The system of H. F. Freund, which is patented in Austria-Hungary, is on similar principles. The bricks have, however, in addition, a groove on the bottom as well as on the sides. The bricks which are very large have on their lower surface a swallow-tail groove, two inches deep, parallel to the long edge and on the upper side a corresponding projection so that an interlocking joint is produced; the end joints are closed by pieces inserted as in the preceding system. In putting up the wall the bricks are laid up dry, the openings for the small pieces are poured full of mortar and the pieces pressed in. Mr. Freund has built a house of such brick, as well as a round water-basin and divers models showing the many uses to which these bricks may be put. The bricks are made by means of a special die and cutter on any plastic clay brick-press. A beam built up dry with such brick projecting freely a distance of 1½ meters illustrates the bond obtained by means of these bricks.

It is not necessary for me to go into a discussion of the different machines exhibited by Hertel and Schlickeysen, as their construction is well known to all. I should like, however, to call attention to the advantages of a new die made by Schlickeysen, which can be adapted to any stiff clay machine. An easy flow of clay from the die is brought about by the fact that the inner surface of the latter is constructed of overlapping scales of zinc, iron, or steel. At the back of these scales or plates there is a continual circulation of water, some of which is continually oozing out between the edges of the plates, thereby lubricating the stream of clay. The earlier attempts to facilitate the flow of the clay by lining the die with linen or leather were not successful, as they had to be renewed almost daily, and the present device of Schlickeysen will work for a number of weeks without attention.

The brick machine exhibited by L. Henrici, of Vienna, is similar in all respects to the Hertel machine, even down to the cutting apparatus, and it is hard to see where any improvement lies. The improvement claimed is in the composition of the metal used for the bearings. The changes in the new Henrici machine are in connection with the cutting apparatus, and in the delivery of the bricks to the cars. The taking of the bricks from the belt to the cars and also the cutting up of the stream of clay into bricks is done automatically, thus effecting a saving of labor. The force exerted by the column of clay moves the roller table forward; the clutch of a shaft beneath the table is thrown in and by means of a pinion and rack gear the frame carrying the wires is drawn from the side through the clay column. The lower end of the belt which carries away the bricks is slanted at an angle of 30°, and the car to receive the bricks is brought under the end of this belt on an inclined track so that the bricks are delivered upon it automatically, since the deck of the car is provided with rollers. As the machine has never had any practical test it is difficult to say whether or not it is practical.

Less known than the previously mentioned machine, but worth examining on account of the solid manner in which they are built, are the machines of Schmerber Bros. I saw these machines in operation a number of years ago in southern Germany and they made a very good impression on me at that time. The Messrs. Schmerber exhibit a double pair of rolls which is connected with the brick press by an endless belt, also a hollow brick press and a lime-sand brick press. The rolls of the crusher are of considerably smaller diameter (about 30 cm.) than we usually find in brick machines; at the same time they are supposed to revolve at a much greater velocity and consequently their capacity is just as great. These smaller rolls have the advantage that they will not take in stones greater than walnut size, and when such are present in the clay in small quantities only, they can easily be removed by means of an iron hook.

On a previous occasion I have observed the fact that these rolls in crushing a clay mixed with lumps of soft sandstone, but not containing any hard pebbles, delivered the clay to the belt in sheets not more than to 1½ mm. thick, whereas, all other types of rolls are seldom set for less than 5 mm.; still these rolls furnish enough material for a daily output of 12,000 to 15,000 bricks.

The brick machine consists of a cast-iron vertical pug mill, above which is the gearing for operating it, while at the base the bar of clay issues horizontally; the cutting apparatus differs from others, in that the bar of clay instead of being received upon a series of rollers, issues on little plates with a top layer of plaster which is kept damp. The cutting wires are fastened on a frame which is held above the bar of clay and cuts through the bar from top to bottom instead of sidewise. The bar of clay is cut by the wires into three or four bricks, which are then lifted off on the board previously mentioned, and placed on the elevator, a fresh pallet being put upon the machine to receive the next portion of the clay stream. In this way the shape is retained much better.

The hollow brick presses are also arranged for steam power and the pressure is applied in somewhat the same manner as in the case of the Sachsenberg brick machine, that is, by means of two pressure rolls. The pugging machinery and rolls are not directly connected with the press, which is simply supposed to receive the thoroughly prepared clay. The die, which is of bronze, discharges the stream of clay upon a series of plaster-of-Paris rollers. These plaster rollers which have thus far been a characteristic feature of the Schmerber machine are to be recommended, because on the one hand they are cheaper than rollers covered with cloth, and on the other hand, they are easier to wash off and can immediately be used again; furthermore, the clay is not at all apt to adhere to them because they are usually thoroughly saturated with water, this saturation being accomplished by immersing them over night; the water in which this is done is first rendered milky by mixing it with powdered plaster of Paris.

By all means the most interesting machine of the Schmerber exhibit is one for the manufacture of the so-called French roofing tile, its capacity being 7,000 to 8,000 daily. The main feature of this machine is a five-sided prism revolving intermittently around a horizontal shaft. Each side of the prism represents the lower half of the mold, the upper half being operated by an eccentric from above and possessing an up-and-down motion. The rotation of the prism is intermittent. As each side approaches the highest point of its rotation, a slab of clay is laid on it, and when this highest point of the revolution is reached, the prism stops for a short interval, during which the top plunger comes down slowly on the slab of clay and the tile is thus molded. The prism then continues to revolve, and as each tile reaches the lowest point of the prism's revolution it drops off and is received upon a wooden pallett. The slabs of clay are roughly molded in a stiff clay machine. The molds consisting of plaster of Paris cast into cast-iron boxes are fastened to the prism by means of bolts; the plunger carries also a plaster die which presses the upper half of the tile. The pressure is applied slowly but is great enough to fill all the recesses of the mold and to squeeze the excess of clay through the thin joint between the two halves. After the tiles are dried somewhat they are trimmed, the press-seams being removed in this operation.

The prices of the different Schmerber machines are quoted at the factory as follows:

	Francs.
Double roll crusher - - - -	2700
Brick machine - - - - -	3100
Wire-cutting table for the above - -	850
Roofing-tile press - - - -	5800
Molds for the same - - - -	380
Hollow brick press with two dies - -	3600
Hand-press for roofing-tile - - -	1450
Small press for steam- or horse-power - -	2500

Shafting and setting-up of machines are not included in these prices.

The roofing-tile press of E. Laeis & Co., in Trier, is a hand-press in which the upper half of the mold is pressed down on the lower half in the vertical direction. The plaster mold is moved beneath the plunger on a sliding plate; motion is imparted to the plunger by means of screw and wheel. After the screw has been turned back the mold containing the pressed tile is removed and turned over on a hinge so that the tile falls on a pallet. A brick machine which differs considerably from most German machines in the method of treating the clay is exhibited by T. S. Derkam, of Leeds, Eng. The machine follows the hand-molding process, and every brick is pressed in an individual mold in which it is removed from the machine and struck off. While the machine possesses certain very desirable features, at the same time it has objections which would interfere with its extended use. Still great improvements are possible on this machine, and I would seriously recommend a careful study of it to brick manufacturers.

The pugging of the clay takes place in a vertical pug mill which is entirely open at the lower end. At this end and close to it there revolves a molding table forming the bottom of the pugging cylinder in which there are six molds with movable bottoms and sides lined with steel plates. These movable bottom plates run on a circular inclined track which is arranged underneath the molding table, and which is constructed so that each bottom plunger shall be in its lowest position when it is directly under the pug mill, and in its highest position when the finished brick is ready to be received from the mold. As the table revolves, the empty mold comes beneath the pug mill and is filled with clay, the excess of which is scraped off the surface of the mold as the latter passes out from underneath the sharp edge of the mill, and as the revolution continues the filled mold passes below a fixed iron plate which nearly touches the surface of the table; when this position is reached the bottom plunger is raised by following the elevation of the track, and is forced upwards against the top plate, thereby bringing a pressure to bear upon the clay. As the revolution continues the pressed clay passes out from under the iron plate, the bottom of the mold gradually rises, the brick comes up to the level of the table and is automatically pushed off on an endless belt. The bottom of the mold is kept lubricated with petroleum, or a similar lubricant. The machine is said to have a capacity of 15,000 bricks in ten hours and requires eight horse-power. The bricks are very smooth, clean and firm enough after molding to permit hacking several courses high. Owing to the many wearing parts, it stands to reason that there must be great wear and tear on the machine, and it is probably best adapted to a smooth clay free from sand. There also seems to be an objection to the lubricating of the surfaces with oil, and it would seem better to sprinkle clay dust or molding sand into the mold instead. Finally, one great objection to it is that all particles of clay, which are forced out from beneath the pug mill and from between the top plate and become covered with grease, are automatically swept into the empty molds, and are pressed into the lower portion of the brick.

The price of this machine, together with a directly connected engine, is 430 pounds sterling, or without the latter 320 pounds sterling.

The so-called dry presses are represented by one machine only, a German one made by Louis Jäger, in Burtscheid, near Aix-la-Chapelle. Since attention has often been called to the fact that it is not the province of the brick industry to produce objects which on the exterior have the appearance of bricks but lack their durability, I need not say much about this machine which, however, may yield a very good product under favorable conditions; at the same time I cannot refrain from quoting section No. 1 of the various claims made for this machine, *viz*: "This machine can work any material which is adapted to burning without any preliminary preparation and in just the condition in which it is dug." At the exposition, Mr. Jäger astonishes the uninitiated by showing them how it is possible to make a beautiful sharp-edged brick from even common garden soil, and calls especial attention to the fact that he has no better material at hand. In my opinion he could not get a much better material than common garden earth which by many years of careful spading has been brought to a most homogeneous condition; I fear that if he took a fresh lump of clay he would not have such good luck.

The drain-pipe press of Page & Co., as an example of the well-known Whitehead press, does not show anything of particular value, but brings to our notice the fact that an agency has been established in Vienna for this machine, thereby indicating an enlarged field.

There only remains to be described the large sewer-pipe press exhibited by Sachsenberg Bros., of Rosla, and I will discuss this in my next report.

THE MANUFACTURE OF SEWER PIPE

The production and export of sewer-pipe to Germany has been, until recently, monopolized by several English firms, at least, the experiments made by several factories at home have succeeded only in satisfying a purely local demand. The fact which impresses the visitor is that, in spite of the great effort which German and Austrian manufacturers of sewer-pipe have made in recent times, all of the sewer-pipe used at the exposition, has been supplied by the firm of Jennings & Co., of Lambreth, near London. We cannot say that the quality of the pipe delivered by Jennings & Co. is the very best which this firm can make, since they are all under ground ; as far as is known it stands in marked contrast to the products which usually come from this factory and shows marked inferior durability. I am not in position to say just why the German sewer-pipe industry is not more developed, whether it is the old German notion that foreign goods are always better, or whether the English products in spite of the high freight are still cheaper than the German ; however, it cannot be denied that a great number of domestic manufacturers produce ware which is in every way equal to the English sewer-pipe.

The material which is so widely distributed in Germany in the refractory clay of the lignite formation, which for this branch of the industry is easily available and so well adapted to the manufacture of sewer-pipe, should insure the success of this industry in Germany, and supply at least the domestic demand as soon as the methods of manufacture are so developed that the ware can be put on the market at the price of the imported pipe.

On an earlier occasion I described the method of manufacture of sewer-pipe as carried on at the works of Jennings & Co., at their Poole factory, and it would be impossible to find any German works of the same character equipped with so many mechanical aids. Though the capacity of the best German works may seem rather limited in comparison, at the same time, if the contractors and builders once became convinced that the domestic ware is at least equal to the imported, the increased patronage would soon permit the German works to greatly improve the mechanical details, and to stand in the market on an equal footing with foreign establishments.

While sewer-pipe cannot in every case take the place of iron pipe, at the same time it has in many cases certain advantages. It is in the first place much cheaper, if not ruled out by the condition of great or variable pressure, or if subjected to blows; it is much cleaner, and not affected by corrosive acids, or liquids derived from the decomposition of organic matter, so that in certain cases, as in the chemical industry, its place can not be taken by any other kind of pipe. It is of course to be understood that as these pipes are generally used for conveying liquids they must be thoroughly impervious to liquids. A glaze alone is not sufficient to stop the permeation of liquids, so the body of the pipe itself must be thoroughly impervious. Products which have a porous body covered by a lead glaze are necessarily excluded from many uses. Many works, the majority of those exhibiting at the exposition, show pipes made of hard-burned fire-clay which is covered either by a slip glaze, or still better a salt glaze, and these products, especially if the body be vitrified, will always demand preference.

While in the following lines I make mention of the chief representatives of the sewer-pipe industry, at the same time I cannot go into a discussion of all those exhibits which show but a small assortment of sewer-pipe in addition to other wares. Among the foreigners there are only a few who deserve mention, and some of their works have already been described in other articles. Among these are Jennings & Co., Doulton & Watt, and Doulton & Co., and I must say that most of the exhibits of the first-mentioned firm are of high grade and far superior to the ware which was supplied for the exposition. Among the German factories worthy of mention, on account of the high grade of the products, is that of F. C. Fickentscher, in Zwickau, who makes a specialty of sewer-pipes of large dimensions up to 1 meter in diameter, these being covered, sometimes with a salt, and occasionally with a slip-glaze; there is also the exhibit of M. Jahn, in Bitterfeld, whose pipes, while not of great dimensions, still show a very dense body and strongly glazed surface, which is covered with a slip-glaze made more fusible by a subsequent salt-glaze. Of equal durability are the products of F. Naumann, in Rottendorf, Nordmann Bros., in Altenburg, and of Hugo Jannasch, of Bernburg, whose ware is sold under the name of "Ascanialith," and has a gray, porcelain-like body which is covered with a thin leadless glaze. The last-named exhibitor also shows coils of pipe for condensers.

The industry of the Nassau stoneware district, whose highly plastic and densely burning clays are well-known and especially adapted for stoneware, has also sent many interesting exhibits. It seems that the development of the sewer-pipe industry in this pottery district has been retarded by the lack of railroads, and hence has not reached the development which it deserves. Among the exhibitors are the Messrs. Gerz & Sons, J. Thewald, of Höhr, and C. Knoedgen, of Baumbach. Good sewer-pipes are also exhibited by Gelhard Bros., of Peterskirchen, and C. Graf, of Degendorf, in Bavaria.

Of less value are those sewer-pipes made of fire-clay covered with a lead glaze, and exhibited by the Chamotte-und-Thonwaarenfabrik, of Ruppersdorf, in Silesia, as well as a number of pipes made from a red brick clay, provided with separate collars for joining the different sections, exhibited by K. Zeller, of Allwiller, in Alsace-Lorraine, and finally some pipes already partially destroyed by lime fragments made by E. Biehl & Co., at Waiblingen.

An example of the progress made in the German sewer-pipe industry, especially with reference to the production of large pipes, is shown in the Austrian division by ware which possesses a vitrified body and is salt-glazed, bearing the character of the English products.

A very rich collection of all sorts of piping—water-pipes, chimney pipes, etc.—is exhibited by Messrs. Lederer and Nesseugi, as well as by V. Schäffner, in Floridsdorf, near Vienna; they are partly black and partly yellowish brown in color. Of especially great size are pipes which are used in the construction of acid towers. These are of great density and hardness, and are exhibited by the clay works at Königssaal, in Bohemia, and the works of the Austrian Society for Chemical Industry at Aussig and Kralup. A specially fine appearance is shown by the hard products made at the clay factories of von Millers and Hochstetter, in Kruschau, Austria, as well as at the factory at Mostau.

It is undoubtedly true that, since the distribution of materials suitable for making sewer-pipe is very extensive, the increased activity in this branch of industry is caused by the more extensive use of proper machinery for such work, and that by freely using it, Germany will be able to combat the prestige which English goods have gained. The old method of molding pipes from sheets of clay around cores of plaster of Paris, or in molds of the same material is no longer employed in large factories for the production of straight pipes, but only for complicated shapes such as elbows and branches, and for these cases only where they cannot be made by the putting together of straight pieces.

The presses which with few exceptions are now used in all factories at the present day, while they are a great improvement on early methods, each manufacturer possessing some special design devised by himself whose construction he covers with the utmost secrecy, are on the whole of surprisingly small capacity, in comparison with the great amount of clay worked by the later pipe presses of Clayton, Murray, and Robinson, these being the ones most used in the English industry. Jennings & Co. make only smooth pipes on the press and form the flanges by reinforcing and widening the pipes on the wheel. This, however, is not satisfactory as the flanges thus made are very liable to split. The attaching of flanges turned on the wheel or cut from wider pipes, formerly quite generally practiced, gives rise to similar defects since a difference in the stiffness of the clay will cause cracking. Hence it is the general aim of manufacturers to produce pipe and flange in one piece, not only in order to produce a better quality of pipe, but also to decrease the cost.

It is, therefore, worth noticing that Sachsenberg Bros., of Rosla, have set up one of their great pipe presses in the German exhibit, and show it in operation. This machine is already in use in a number of German and Austrian factories. As auxiliary machines, there are exhibited a horizontal pug mill, the opening from which can be regulated by means of a slide, also an elevator to hoist the balls of tempered clay, the latter consisting of an endless belt, 30 cc. wide, to which iron buckets are attached. The pipe press is similar in its construction to the Sachsenberg brick press, but differs from it in that the cylinder and the die are in a vertical, instead of a horizontal position, the clay being forced out at the lower end. The cylinder has such dimensions that dies large enough to form pipes 1 meter in diameter can be attached. The dies are circular, and in the middle there is a hemispherical bell curved upwards, and fastened by means of a spider in such a position that a ring opening is left corresponding to the thickness of the pipe. Below the opening from which the clay emerges, the die widens to the size of the outer dimensions of the flange, and the interior surface of this portion of the die is lined with plaster of Paris, which is kept saturated with water in order to prevent the sticking of the clay. Underneath the mouthpiece is a table which receives the pipe as it issues from the machine, this table being counterbalanced and moving up and down. To produce the flanged end of the pipe a wooden block, whose dimension corresponds to the interior width of the flange, is inserted and held in position by the counterbalanced table. The machine is now set in motion and the clay forced from the die until the space around the wooden blocks is filled and some of the clay projects. The table is now lowered and the flange core removed, the lower end of the clay being cut off smooth with a wire, and the table once more raised to receive the pipe as it issues from the machine. Smaller pipes can be set directly on the drying boards, but for diameters exceeding 300 mm. a wooden block is set within the flange so that the weight of the pipe cannot press it out of place. These wooden blocks as well as the drying boards have a hole in the middle in order to permit the circulation of air through the interior of the pipe during drying. For the manufacture of very large pipes, that is, those having a diameter and length of 1 meter, whose weight when green is about 600 pounds, it is of course necessary to use a special form of crane and truck to transport them to the drying place. The capacity of one of these machines, as quoted by Messrs. Sachsenberg, is as follows: for socket-pipes, whose diameter (interior) is 100 mm. when burned, the output is 700 pieces in ten hours,

	Pieces.
120 mm. in diameter	600
160 mm. in diameter	500
200 mm. in diameter	300
240 mm. in diameter	250
400 mm. in diameter	150
500 mm. in diameter	75

For the very large pipes it is not possible to obtain thoroughly reliable data. Elbow pipes can be made on this same pipe press up to a diameter of 200 mm. This is accomplished by bending the socket-pipe while being forced out from the press according to a pattern. For large pipes, however, this method of molding is not applicable without producing an elliptical section of the pipe, causing it to pinch, and for such cases the old method of using plaster molds has to be retained.

Elbow pipes, whose diameter is 160 mm. and whose length 650 mm., can be molded at the rate of 270 in six hours. The trimming of the pipes and the grooving of the interior of the sockets (to assist the adhesion of the cementing material used) is done when the pipes have become quite stiff so that they may be handled without being dented.

THE BRICK WORKS AT THE WIENERBERG

The visitor at Vienna, especially the brickmaker and builder, finds not only a rich field for study at the exposition, but also derives much information and profit from a visit to the Wienerberger Brick Works. This work has gradually been developed from a small beginning, and at the present day represents an establishment, one of the largest of the world, which has an international reputation.

The use of the splendid clay which is found on the southern slopes of the Wienerberg, dates from a very early period. In 1775 there was erected, on the spot now occupied by the large brick-works of Inzersdorf, a small brickyard, at the command of Empress Maria Theresa, which was supported by the state and supplied materials for the fortifications. Even at the beginning of the present century the total production of this brick-works was about 1,500,000 bricks annually, and served to supply, practically, the entire demand of the city of Vienna at that time. In 1820 Mr. Alois Miesbach rented this brick-works and laid the foundation of the Vienna clay-working industry. In the year 1826 he obtained possession of the Inzersdorf and Steinhof properties, and in 1830 became the sole owner of the brick-works on the Wienerberg. From this period dates the continual growth of the brick-works at Inzersdorf, around which there gradually sprang up additional works, as those at Bösendorf, Biedermannsdorf, Guntramsdorf, Leopoldsdorf, Laaerberg, and Hernals. In the year 1851, the clay-working establishment of Inzersdorf was founded, and the products, both brick and terra cotta, found their first important application in the construction of the gigantic building which served as the Royal Artillery Arsenal.

In 1857 the founder of these works died, and the ownership passed to his nephew, Mr. Heinrich Drasche. Since the 1st of March, 1869, the works have been under the direction of the Wienerberger Brick and Building Company, which is capitalized at 7,000,000 florins.

Under the management of Drasche the Wienerberger works continued to expand and the number of brick kilns of the old type in 1864 amounted to 250, each one having a capacity of 80,000 to 120,000 bricks, and the annual capacity was 130,000,000 bricks.

At this time a great change took place in the arrangement of the brick plant by the introduction of the Hoffmann continuous kiln. Mr. Drasche acquired the sole right to Mr. Hoffmann's services for a district of four (German) miles radius in the construction of the new kiln. In 1865 the first pair of continuous kilns was operated, and from this time on, the old kilns began to fall out of use more and more. In 1869 the number of continuous kilns in operation was twenty-two, and, with the exception of two which were round, all were oblong in shape. At the present time there are thirty-three among them, five double kilns, each of which consists of twenty-eight compartments and is fired by two sets of fire-holes at the same time so that the works is in position to produce daily 1,000,000 burnt bricks. In 1872 the total production was 170,000,000 and the anticipated production for the present year is 210,000,000. It was only possible for a works of this magnitude to supply the demand for bricks of the exposition, 20,000,000, and to do it without inconveniencing the extraordinary demands of the local markets, in the time of three months.

In order to give an idea of the enormous dimensions of this works I will give the following figures taken from different sources.

The works of the Wienerberger Brick and Building Company consist of nine different plants which are arranged in the form of a crescent around the southern half of Vienna.

I. The largest is the brick works at Inzersdorf, which covers an area of 417 jochs (138 square klafters), 1 klafter being equal to 1.896 meters, 1 joch to 1600 square klafters).
II. The brick-works at Hernels, covering an area of 40 jochs and 591 square klafters.
III. Two combined brick-works at Laaerberg, 100 jochs and 786 square klafters.
IV. Brick-works of Laaerwald, 95 jochs and 1328 square klafters.
V. Brick-works at Leopoldsdorf, 32 jochs and 1449 square klafters.
VI. Brick-works at Biedermannsdorf, 89 jochs and 60 square klafters.
VII. Guntramsdorf brick-works, 63 jochs and 1449 square klafters.
VIII. Bösendorf brick-works, 42 jochs and 649 square klafters.
IX. The clay works at Inzersdorf, for the manufacture of terra cotta, majolica and ornamental brick.

A second clay-working plant of magnificent dimensions is at present being constructed at the summit of the Wienerberg, and a portion of it is to be in operation in the fall, the balance by next summer; it will employ 600 workmen, and the products will consist of majolica stove tiles, glazed and decorated wall tiles, hard-burnt encaustic and mosaic floor tiles, terra cotta, majolica and Robbia ware.

The area devoted to brickmaking owned by this company covers 882 jochs, of which half has not yet been utilized and only about 100 jochs of clay land has been worked to a depth of fifty feet. Borings in the clay deposits have shown a depth of 500 feet without striking the bottom of the strata, and hence the raw material still available corresponds to 20,000,000,000 bricks. The area covered with the permanent buildings of the eight brick plants comprises 28,671 square klafters; to this there are to be added 74,025 square klafters of drying and other sheds, making altogether an area of 102,696 square klafters roofed over.

The length of the drying sheds is equal to six German miles; that of the tramway tracks to 7,738 linear klafters. Most of the bricks are made by hand, there being about 1,000 molding tables set up between the drying sheds; only a portion, about 26,000,000, are molded by machinery, and for this purpose the company has thirteen Hertel brick presses. The engines which are used to run the machines and also to pump water are six in number, and have a total of 147 horse-power; the steam is supplied to them from ten boilers.

For the burning of the bricks there are thirty-three Hoffmann continuous kilns, there being among this number five double ones with twenty-eight chambers, the others having twelve to sixteen chambers, their capacities being from 8,000 to 20,000 each, and they have a total annual capacity of 200,000,000 bricks; in addition there are thirteen arched kilns of an old construction in use, as well as four pottery kilns, one kiln for fire-brick, also three muffle-kilns for the manufacture of terra cotta and majolica. Of the works named, the brick-works at Inzersdorf is the largest whose capacity represents about half of the total capacity: it has thirteen ordinary and three double continuous kilns, the latter having twenty-eight chambers. The most important product of these works is a common building brick, which is sold chiefly in Vienna and vicinity. Most of the bricks are carted into the city and 900 horses are used for this purpose; about 20,000,000 are shipped annually by canal and the remainder go by train.

The balance of the production consists of ornamental bricks, terra cotta, majolica building and garden ornaments, yellow and red pressed-brick, roofing tile, drain tile, paving-brick, etc. The company also exports quite extensively to Germany, Switzerland, Russia, Italy, England, and even to the Orient and America.

The size of the bricks is according to the legal specifications, 290 x 140 x 65 mm., and therefore nearly one-third larger than the present German standard size, but it is probable that with the adoption of the metric system in Austria in the near future, the size in use in Northern Germany will be adopted.

The establishment is managed by a board of directors consisting of nine members, whose sessions are attended by the former proprietor, Mr. Drasche, as honorary adviser. The highest official is the general secretary who directs the commercial as well as the technical side of the business. In direct charge of the brick-works are three inspectors; each separate plant has its superintendent who is assisted by an accountant and a number of foremen. The mechanical equipment and repair shops are in charge of two engineers, the experimental laboratory is conducted by a chemist and the chief modeler directs the work of the drafting and modeling department. The company employs 58 officers, 36 machinists and foremen, and 6,000 to 7,000 workmen.

The workmen are mostly Bohemians and Italians, some of whom return to their homes in winter. The Bohemians are the best brick-molders, although the Italians make about one-third more bricks than the others in a given time, but the product which they turn out is not so good and gives rise to more waste. There are a few German and Austrian hands employed, who are mostly mechanics, potters or kiln men, and rarely brick-molders. The workmen live mostly in the company's houses, about 200, are exempt from rent and receive free fuel.

Connected with the works is a hospital, and there is also an association for giving aid to the sick or otherwise disabled employees. The treasury of this society is supported in part by contributions from the employees, in part by the fines deducted for various small neglects. The health of the men is in charge of a chief and six assistant physicians. There is also a kindergarten for the children of the employees. The officials likewise have a mutual aid association which also provides for pensions according to the principle of the government pension system.

On leaving the city by the Vienna-Triest road and passing that old land-mark of Vienna on the summit of the Wienerberg, the spinning woman at the cross, there will be noticed the Inzersdorf Brick Works at the foot of the hill. Still almost hidden by the steep clay banks cutting into the hill there comes into view an ocean of many hundreds of gray roofs. Out of these there appear in regular intervals about a dozen high stacks 150 to 180 feet high, whose purpose becomes at once evident to the brickmaker. Thus we have before us one of the largest industrial establishments, the largest brick-works of the world, in a continuous aggregation of buildings divided only by the road.

The regular arrangement of all buildings in parallel lines and equal distances apart, in fact the whole arrangement of the works, shows that it is laid out on a great and systematic plan, and is not in any way patched together or cramped.

The clay pits belonging to the brick-works are situated to the northeast of them. The Inzersdorf Brick Works, employing more than 3000 workmen, is divided into six separate divisions with independent technical and commercial superintendents, whose work is controlled by a central office. However, these divisions are not equally large since the construction of the various subworks was carried out at different times, and since also the capacities are governed by the dimensions of the continuous kilns used.

The extent of the clay deposit or "tegel," as the blue clay is called locally, has not yet been accurately determined, and difficulties stand in the way of these borings. An actual thickness of 500 feet is, however, known to exist. The deposit is covered by a layer of 2 to 3 meters of sand, gravel, and loam, and below this there are more or less plastic layers of yellow clay separated by thin veins of sand; under this at a depth of 10 to 12 meters we find a blue clay, separated by laminae of molding sand and interrupted here and there by sharply defined layers of fossiliferous marl; under this there is again blue clay which extends down to a bed of calcareous clay marl at a depth of over 20 meters, this representing the lower limit of the pit as now opened up.

The digging of the clay is mostly carried on in winter; the stripping and filling in is done in summer, and also the digging of certain lean layers, which can be fed directly to the machine without previous weathering. The work is paid for per cubic unit of clay mined.

The clay is worked in benches, because this method permits the separation of the different varieties. Certain layers are used for the manufacture of pipes, pressed-brick, and roofing tiles; others on account of the shells have to be washed, and finally the fine sand is used for sanding the brick molds; the remaining clay is worked by falling the bank, thus thoroughly mixing the lean yellow clay and the fat blue clay used in making the common brick.

The readiness with which the clay weathers and slakes enables the company to follow the old-fashioned style of brick-molding, this being the one to which the Italian and Bohemian laborers are accustomed; at each molding-table a man and woman usually work together. It is the business of the man to mix the clay, to wet, temper and deliver it on the molding-table; the woman does the molding and places the brick on the drying floor; she also tends to the edging and hacking of the bricks under the sheds, being assisted in this at times by the larger children. The clay for a day's work is generally prepared by the laborer in the evening hours of the preceding day; this clay is usually taken from a supply dug during the winter. It is worked up as much as possible by means of a hoe and then spread out in a layer only a few inches thick. This being done water is thrown over it with a scoop, a second layer of clay put over the first, and more water thrown on, until a sufficient quantity is piled up to soak for the next day's work. The clay thus softens up during the night, and it is given one more mixing in the morning before being wheeled to the molding-table.

The molding-tables are set up between the drying sheds; the space in which the molding is done is bounded at one end by the clay heap, and at the other end by the continuous kiln, so that the clay moves in a straight line towards the kilns. The molding of the bricks is done in wooden molds, which are sanded and bound outside with hoop-iron. The wooden bottom bears a metallic plate with the name of the firm. A lump of clay is cut off from the tempered heap equal in volume to about one and one-half bricks, and is then rolled into a ball on the sanded table. It is then thrown into the mold and the latter brought down on the table several times with some force in order to force the clay into the corners of the molds. The excess of clay is then cut off at the top of the mold by means of a wire, or wooden scraper. The mold is then carried to the drying-floor and the brick dumped. One woman brick-molder works at each table and seldom makes more than 1500 bricks in a day, her average output being 1200. The preparing of the clay, the molding, drying, hacking, etc., is paid for by the thousand, the rate being governed by the distance which the brick must be transported. Those workers who show special skill, turn out most bricks and work the clay most thoroughly, receive special premiums at the end of the campaign and are also granted higher rates.

It has been found, however, that during the last five years wages increased 30 per cent while the average production decreased 20 per cent, so that the earnings increased at an extraordinary rate. The large bricks are made in the same way as the smaller ones, there being three sizes, the largest of which is 24″ long, 8″ wide and 3″ thick.

Two branches of the Inzersdorf works use both hand- and machine-molding, the one having four, and the other six presses, which are capable of making either solid or hollow blocks. Tracks are laid from the presses to the drying-sheds.

The manufacture of roofing tile, pipes, pressed-brick, etc., is carried out at certain branches of the works; for this purpose only washed clay is used.

The pressed-brick of all kinds in buff and red colors, and of all shapes and profiles are made in part by repressing, but mostly by hand, in sanded wooden molds, but the drying is carried on more carefully than in the case of the ordinary hand-made brick. A woman molder does not make more than 500 pressed bricks per day of the ordinary Vienna size.

In northern Germany where sand molding is not practiced to any extent the opinion exists that it is not possible to produce a nice brick in this way; here, however, where the pressed brick manufacture is carried on on such a large scale, it is seen that the contrary is the case, and we find that with the proper selection of sand, and clay of the right consistency the bricks are almost faultless, and are much less liable to subsequent discoloration than those which are pressed in wet molds or repressed in molds lubricated by some form of greasy material. The setting, burning and drawing is paid for by the thousand. The fuel used is coal-slack, and the amount used is regulated by its price and heating power; sometimes powdered coke from gas works is employed or even lignite-slack. The coal used in the year 1872 including that for firing the boilers and old kilns amounted to 1,200,000 cwt. for a production of 170,000,000 bricks; this is equal to the quantity used in 1858 before the introduction of the continuous kiln for a capacity of 85,000,000. On the average, 4 cwt. of coal are allowed for burning 1000 bricks.

The quality of the products produced is of the highest grade and no pains or expense is spared to keep the grade as high as possible; it is for this reason that the products of this works are so often given preference.

The following table giving the cross-breaking and crushing strength of the different products indicates their high quality:

a. CROSS-BREAKING STRENGTH

Tests made by Prof. Rebhan, Vienna

	Broken with a load of pounds per inch.	Breaking coefficient.	
		Kilogram per square cm.	Pounds per square inch.
Common brick	1419	42	603
Common arch brick	2417	52	737
Ordinary face-brick	2255	65	925
Red face-brick, washed clay	1711	50	708
Buff face-brick, washed clay	2875	84	1187
Solid machine-made bricks	1662	49	692
Hollow bricks, two openings	1785	54	766
Hollow machine bricks, 3 holes	1812	84	1194
Hollow machine arch brick 16 holes	1307	39	554

b. CRUSHING STRENGTH

Tests by Prof. J. Bauschinger, Munich

	Name of works.	Crushing strength of whole brick in tons. 1 ton = 1000 kg.	Crushing strength.	
			Kilos per square cm.	Pounds per sq. inch.
1.	Wienerberg.			
	a. Common hand-made brick	77.5	188	2613
	b. Common machine brick	100.0	230	3197
	c. Common face-brick	77.0	183	2544
	d. Buff face-brick, washed clay	80.0	205	2850
	e. Buff repressed brick, washed clay	100.0	230	3197
	f. Red face-brick, washed clay	81.0	200	2780
	g. Red face-brick, repressed, washed clay	85.0	195	2711
	h. Common arch brick	48.0	125	1738
	i. Porous arch brick	10.0	27	375
	k. Hollow machine brick, 3 holes	19.5	50	695
	l. Hollow, porous arch machine bricks, 3 holes	5.5	19	264
	m. Vitrified bricks	53.0	240	3336
2.	Bösendorf.			
	Common hand brick	74.5	180	2502
3.	Leopoldsdorf.			
	Common hand brick	71.0	175	2433

b. CRUSHING STRENGTH.—*Continued.*

	Name of works.	Crushing strength of whole brick in tons. 1 ton = 1000 kg.	Crushing strength.	
			Kilos per square cm.	Pounds per sq. inch.
4.	Laaerwald.			
	Common hand brick	64.0	158	2196
5.	Laaerberg, I.			
	Common hand brick	96.0	236	4281
6.	Laaerberg, II.			
	Common hand brick	76.5	196	2725
7.	Guntramsdorf.			
	Common hand brick	65.0	162	2252
8.	Biedermannsdorf.			
	Common hand brick	78.0	200	2780
9.	Hernals.			
	a. Common hand brick	62.0	158	2196
	b. Common machine brick	90.0	205	2850

The exhibit of the Wienerberg Brick Works and Building Company consists not only of the 20,000,000 and odd bricks which have been put in the different exposition buildings, and the large quantities of terra cotta, but the company has in addition erected a large structure which shows well the many directions in which its materials can be used. This excels any other clay-working exhibit at the exposition. It is this—the triumphal arch, which in the second zone divides the art hall and the buildings devoted to the products of agriculture and forestry, and which also shows the customs of the various rural populations, —the so-called international village.

This noble triumphal arch, with three portals, is built in the Rennaissance style. The central passage has a high semi-spherical arch, the lower side passages flat arches. The façade is beautifully decorated with majolica terra cotta, but without being overloaded. Between the three entrances leading to the exhibition building are fluted columns with Corinthian capitals, supported by panels decorated with bas-reliefs and representing different mythological characters from the Hercules story. The outer entrances are decorated with unglazed tiles, showing animal and floral decorations. The decorations around the middle entrance are of the same character, but those portions which are in relief are decorated with rich, enamel colors. The semicircular, middle arch is decorated in the same manner, colored ornaments on a bare red ground. Over the arches there are four medallions of about 1 meter diameter decorated in Della Robbia style with dark green wreaths, around which are entwined bright colored bands. The medallions consist of flat tiles decorated by painting and represent four allegoric female figures on a blue background.

Above the large medallions there is a frieze representing angels carrying garlands of fruit, made of red clay, the design being decorated in places with a bright enamel. Over this in a triangular space is a group of figures, among them Neptune, and on the wall extending behind this there are additional panels bearing, in relief, figures from Greek mythology, executed in pure white clay. The whole is crowned with the Austrian coat-of-arms of great size, supported by two griffins; the spaces between the different ornamentations are filled in with yellow and red pressed-brick, while around the side entrances, there are numerous small medallions of majolica decorated with angels' figures.

The sides and back of the structure are likewise decorated with terra cotta and red and yellow pressed-brick, as well as glazed brick in white, blue and green colors; in the triumphal arch itself, and in front of it, are different kinds of terra cotta, large vases and statues, as well as a varied selection of brick products.

Worthy of special notice and a masterpiece of potter's work is a fountain decorated with the richest colors in Della Robbia style, which stands directly under the arch, and which was designed by Professor Teirich. The water flows from the mouth of a Medusa's head which is set in a niche against a white background and framed with animal heads and flowers decorated in various colors, the water falling into a great shell supported by two dolphins. This work of art has been purchased by the Austrian Museum of Art and Industry.

Lastly, there is exhibited a most perfect model of the Hoffmann continuous kiln, the use of which has done not a little towards making the Wienerberger Brick Works the successful establishment which it now is.

Means of Transportation

The question of transportation is an important one in all industrial undertakings, especially in the clay industry, and it is therefore well worth the trouble to review briefly those means of transportation which have come into use in recent times. It is probably not necessary to discuss conveyors like wheelbarrows, horse-carts and tramways, which are well-known, and which have been used for a long time, and hence I shall confine myself to those inventions which either convey large quantities in a short time, or which overcome topographical difficulties that would cause heavy construction expenses if the ordinary tramway track were used.

In the first category belong the small locomotives designed for industrial narrow-gauge tracks; in the second, the conveying apparatus of single track roads, the pole and cable roads.

The idea of using steam-power in the transportation of raw material is not new, but the use of locomotives for this purpose has never become very extensive. It is only a few years since secondary narrow-gauge railroads have assumed any importance. The exposition shows us many machines used in this connection made in many variations of construction; the large machine works of all countries compete in the manufacture of small locomotives. I shall not describe the details of the various constructions; it will suffice to describe their general characteristics.

All industrial locomotives have in common a track narrower than the standard railroad track owing to the fact that the grades are steeper and the curves sharper, and that the first cost of constructing the road must be kept as low as possible. While ordinarily the railroad tracks in all European countries are 3′ 8″ wide, the width of narrow-gauge industrial roads may be as small as 24″, although there are some which use the standard railway gauge. The industrial locomotives also do not carry a separate tender for the water and coal supply, but these are carried on the engine itself in quantities sufficient for several hours. The water is carried in tanks attached to the top of the boiler like a saddle, or arranged at the side or beneath the boiler; the coal is kept in containers on the platform, which tend to increase the adhesion of the engine by increasing the weight resting on the four or six wheels.

Of German locomotives of this kind there are to be mentioned those with horizontal boilers made by Krauss & Co., of Munich, by the Machine Company of Karlsruhe, by the Machine and Foundry Company of Darmstadt, by the Hannover Machine Company and the works at Ruebeland and Zorge. Such engines are made also by the machine works of the Austrian Government Railway Company, at Resica, by the John Cockerill Company, at Seraing in Belgium, with vertical boilers, by the Parent Schaken Works, Honel & Caillet, Compagnie de Fives-Lille, Fox, Walker & Co., in Bristol, Henry Hughes, in Loughborough in England, and others.

It is evident that by merely looking at these machines it is not possible to form any opinion in regard to the relative advantages of certain special constructions and those who intend to make use of these appliances must make special inquiries in regard to the efficiency; let it suffice to indicate the sources.

The use of two rail tracks presupposes always a nearly level stretch of land, and where this is not found very expensive grading work must be done. Hence, it is not surprising to find that of late numerous ideas have been brought forward which propose to replace the two-rail roads by single rail systems, especially where loads not too heavy are to be transported short distances and in rapid succession. The first experiments in this direction have been made by General von Prittwitz, in the '30's and '40's, in the transportation of bricks from the brickyard to the construction work, and such a road has been in use for over twenty years in the fortifications at Posen. The loads are here moved on timbers, plated with iron and set on edge which are supported by higher or lower posts according to the topographical conditions, and which form a continuous rail. Two wheels fastened to a frame ran on this rail; to the frame there were fastened two wooden boxes, one on each side of the rail. In order to prevent irregularities in the operation of the tramway, owing to uneven loading, the boxes were kept in balance by wheels running against the side of the rail.

A single rail system including the cars has been exhibited by G. F. Kreisel, of Lugau, near Chemnitz. A mine rail is put down on ordinary ties; parallel to it and adjoining it there are fastened down flat to the ties two planks. The car is a four-cornered iron or wooden box around whose bottom three small wheels are distributed. Two of these wheels are without flanges and run as guide wheels on the planks parallel to the rail; they are located at one end of the box. At the middle of the other end there is a third double flanged wheel which runs on the iron rail. Since the three wheels are not on one axis the car is always in a stable position, even if the track is not level. The track is easily moved in sections, and this is the main advantage of this system; it is not cheaper nor more easily handled than the ordinary tracks since the two planks are more expensive than a second iron rail, and are also less durable, causing, besides, an increase in frictional resistance in spite of the use of but three wheels.

An invention quite similar to that of General von Prittwitz is that of Stoeckel, Breslau, and a piece of track together with a turn-table is shown in natural size outside of the south wall of the machinery hall.

Here an iron rail of ordinary dimensions is used, connected by timber, and beneath the joints supported by heavy posts resting on a secure foundation and braced in a proper manner. On this rail there run two double flanged wheels, one behind the other, whose axles and boxes are fastened to a four-cornered wooden frame. From this wooden frame there are suspended on each side of the rail two wooden boxes which revolve about an axis. They are so connected by means of wooden pulleys and chains that on tipping or lifting one of the boxes the other goes through the same movement. This is very essential in order to maintain the necessary equilibrium. The two wooden boxes which have a content of about one-quarter cubic meter are so spaced that the posts are cleared by a good margin. The cars can be pushed by hand or made up into trains pulled by horse-power.

It cannot be denied that the single rail track of Stoeckel has great advantages under certain topographical conditions over the ordinary two-rail track, but for great differences in level it does not offer such advantages as other systems. For instance, in carrying a track across a valley, river-bed, etc., the first cost becomes considerable, especially since the supports come in frequent intervals, usually every 5 meters; the stability, owing to the great weight of the rails, will be the smaller the higher the posts must be. It seems impossible to overcome very heavy grades without endangering the safety of operation, owing to the great weight of the track, while the same grades are easily spanned by the cable conveyors. For these reasons it is obvious that the Stoeckel system must be confined to comparatively level ground.

Of much greater interest, because permitting of a more extensive application, are the cable conveyors, whose chief representatives are the systems made by von Duecker and Hodgson. Both, however, are exhibited only as models in the east agricultural hall, German section. Both systems have been extensively used of late years for conveying earth, stone, ores, in some cases covering quite long distances. They have in common that the cars do not run on a fixed track, but on a rope or cable. This is by all means the most favorable condition for carrying a load and the supports may be so far apart and of such light dimensions as would be impossible with any other system. The two systems of cable conveyors mentioned differ, however, in that von Duecker does not move the cable on which the cars are carried, but pulls the wheels and stirrups from which the load is suspended by means of another smaller rope. Hodgson fastens the load to the carrying cable and moves the latter along over rollers. Since the cable of the Hodgson conveyor is endless it is necessary to have a double track for conveying the loads to and from the unloading place. In the Duecker system one-track conveyors can be used, in fact, the first one of this kind built was a single track road.

The Duecker cableway connects two points separated by a valley simply by stretching between them a wire rope. At suitable places the cable must, of course, be supported in order not to be bent too much by its own weight. The supports consist either of two or three posts and carry the rope by means of iron shoes or stirrups so that only the lower half of the cable is held while the upper half remains free so that the wheels can pass. These supports are arranged in intervals of 20 to 40 meters, under certain conditions; for instance, in crossing swamps or rivers the distance may even be as far as 100 meters.

The load is suspended from the rope and is contained in a box, a bucket or basket; it is held by an iron stirrup so that the center of gravity is exactly below the rope. By means of two grooved wheels running on the rope and fastened to a frame connected with the stirrups the load can be moved along. The cars are propelled either by gravity or by means of a smaller rope which at one end is wound around a drum. The loads carried should not exceed 5 to 10 cwt. On a two-track cableway on which the loaded cars move in one direction, being returned empty in the opposite way, these are drawn by an endless wire rope which, operated by a motor, is run around sheave pulleys at the ends, and is supported by guide rolls at frequent intervals. A plant of this kind is at Osterode, where gypsum is conveyed from the quarry to the kilns and mill across the Seese valley, the tramway being 400 meters long, 13 meters above the bottom of the valley with a fall of about 6 meters. The empty cars, holding about 500 pounds, are drawn back by means of a rope; the cableway can convey easily from 100,000 to 120,000 pounds in ten hours. A much larger quantity is conveyed by a double-track Duecker's cableway which is used in the construction work at Fort Queleu, at Metz, hauling earth a distance of 2200 meters. At the end points there are single tracks, supported by posts and consisting of flat iron pieces on edge, that are easily moved, which transfer the cars from one cable line to the other; the difference in level is about 40 meters.

In the Hodgson cableway, which has been constructed in England in several instances, and in Germany has been built by the Mansfield Copper Company for conveying ores across a hill, the cable is not fixed like in the preceding system,but runs at the end points around large sheave pulleys which are rotated by power, while every 20 to 100 meters supports, carrying guide rolls, are arranged; the cable, of course, is endless. The load to be carried is suspended from an iron stirrup which is hung on the rope by means of a wooden block fastened to it; the shape of the stirrup is such that it does not touch the guide rolls, and also that the bucket is suspended directly beneath the cable. At the terminals fixed tracks are constructed for loading and unloading. The transmission of the cars from the movable cable to the fixed track is accomplished by running them very close together and allowing at one point the fixed rail to project slightly above the rope, almost touching the latter. In this way the wooden block, from which the car is suspended, is lifted from the rope on to the fixed rail; when arrived on the latter the bucket can be run along by means of two wheels attached to the wooden block. It is at once evident that the Hodgson cableway requires much more power than the Duecker system, owing to the continuous motion of the carrying cable, and it is also subject to greater wear. It can, however, be easily carried around angles and curves, while so far the Duecker cableway has been constructed only in straight lines, though it is not at all improbable that the Duecker conveyor can be made to pass around corners equally as well.

The advantages which cableways offer for haulage compared with other means of conveying, are first the comparatively low first cost (since no grading, bridging, etc., need be done), slight cost of maintenance and large capacity; a Duecker cableway, for instance, can haul in ten hours about 300,000 pounds if the buckets hold 500 pounds, and run in intervals of one minute; on increasing the speed, double this quantity can be conveyed quite easily. Notwithstanding these facts the number of cableways in use is comparatively small, although it is to be expected that, owing to the favorable practical experience with them during the last few years, they will be adopted wherever large quantities of earth are to be hauled. In larger brickworks the difficulties of haulage and distribution of raw materials are the greater the more irregularly the plant is arranged, and here the cable conveyor may be of the greatest value.

ITALIAN POTTERY

The division containing the products of the Italian ceramic industry is without doubt one of the most interesting ones representing this field. The products of art pottery especially arouse the interest, not only of experts, but also of non-technical visitors. We know that Italy was the real cradle of occidental art pottery which was developed in several pottery towns beginning with the 14th century, supported by the liberality of art-loving princes, and based upon the examples of the Moorish clay industry. These pottery towns, Florence, Faenza, Gubbio, have sent their products to Vienna. In part these claywares cater to modern taste and modern requirements; in part, however, they represent reproductions of older pottery, in fact, these are in the majority. In this way the entire development of the Italian clay industry may be studied in its various stages.

The most extensive exhibitor whose products show the greatest variety is the Marquis Ginori, of Doccia, near Florence. The old and famous establishment was founded in 1735 as the first Italian porcelain works, and for a long time it was operated as the only porcelain manufactory which was not supported by a government. The products which are exhibited by it are in part porcelain, in the shape of useful or ornamental articles, statuettes in biscuit, but in the largest part decorative majolica. This class of ware is exhibited as fine show pieces, reproductions of older ware and new pieces in modern taste after modern designs. The technique of these products consists in covering the impure color of the body, prepared from an ordinary, calcareous clay by means of a white, opaque lead-tin glaze and applying on the latter the decoration before burning.

If one considers that on the loose coating of glaze it is almost impossible to correct the decoration, while on porcelain every wrong stroke can be removed by means of a cloth dipped in oil of turpentine, and that in the first case the designs are applied by practiced artists, it is readily understood why these products have always been esteemed so highly and have been used by princes as presents for their favorites.

The number of colors applied in the older majolica and faience is a limited one, and there were used at first only a few shades of blue, green and yellow; to these were added gradually brown, red and violet. Owing to the technical difficulties of painting on a strongly absorbent and easily injured ground, it is quite evident that the lines do not appear as clear and sharp as is the case on other materials more suited for this purpose. We admire on these products not the perfection of the technical treatment or the beauty of the colors, but rather the noble shapes, which in most cases reproduce old Etrurian designs for which the body is much more suitable than the porcelain and fine whiteware bodies, though the latter in other respects are far more desirable. We also admire the beauty of the drawing, the perfection of the curved lines and the expression imparted to each detail by the entire manner of decoration. The painting is, in part, applied to the smooth surface; in part, it is made more prominent in connection with the plastic ornaments, the handles, pedestals, feet, etc.

Beside the products mentioned the same factory exhibits richly modeled ware and objects decorated in the style of English majolica as well as large medallion portraits in bas relief with a white tin glaze in the manner of the Robbia ware; finally there is exhibited household pottery with a beautiful rich blue glaze and in part decorated with gold.

A rich selection of faience is also exhibited by Angelo Minghetti e Figlia, of Bologna. Among the products of these works is one of the largest pottery products. It is a vase six to seven feet high, cup-like in shape and richly decorated on all parts; on the main body of the piece there is represented the triumphal procession of Bacchus in relief.

Among the many products of art faience, special interest is aroused by the pottery of Farina & Co., of Faenza, of Conte

Anibale Ferniani, also of Faenza, whose paintings are usually portraits and coat-of-arms on a flat ground and applied in the luster colors of the old pottery from Faenza and Gubbio, which ordinarily are not obtained in such beauty. The same can be said of Spinazi Giovanni, at Gubbio, whose gold or copper-colored lusters show an incomparable gloss and play of colors. Not only the real products of art pottery, but also household pottery is represented by these and a great number of other factories, though most of them do not possess the pronounced national character of the ware mentioned above. Most of this pottery is so-called fine faience or white ware decorated in the usual manner by printing, lithographic work and painting.

Among the manufacturers who are active in producing these wares there are to be specially mentioned Guiseppe Palmi, at Pisa, and Sebastiano Ricci, at Savonna. The latter has exhibited some faience designed for interior decoration, especially large mirrors and picture frames which are modeled in the richest Rococo style, being decorated with paintings in the same style. These, though showing great skill, cannot be said to make a favorable impression, since the nature of the material does not harmonize with such uses.

Of unglazed pottery products there are a great many in the Italian division; among these we may especially mention imitations of Etrurian vases and examples of excellently modeled statuettes as well as groups which are either unburnt of a red color or decorated with oil colors. Especially noteworthy are the groups of Bongiovanni Vacaro, of Caltagironi, and Andria Galvani, of Pordenone. These groups usually consist of from four to six figures representing peasant scenes, dances, gypsies or brigands' camps, and are simply remarkable when the character of the work and care which has been bestowed upon the simplest details of their modeling is taken into consideration.

The ordinary products of brick factories are shown in considerable quantities, but it is hardly necessary to go into their discussion in detail, as they do not show anything new, and are considerably inferior to the same grade of products made in the northern countries. These products naturally need not be made as carefully, because the building materials of Italy are exposed to a very mild climate, a much milder one than in the northern countries and consequently need not be as resistant to weather. Furthermore, nature has supplied this southern country with such an abundance of natural building materials for decorative purposes that there is less need of going to the expense of producing artificial stone. Only one point need be mentioned, and that is the combination of two different materials, such as clay and asphalt, and clay with cement for the manufacture of tiles, into which different patterns are pressed by means of machinery, the depressions thus produced being filled by asphalt or colored cements. I do not wish to be understood as saying that I consider this method of decorating tile especially commendable for the reason that the difference in the hardness of the materials may cause the ware to wear unevenly, but at the same time the method ought to be mentioned because of its simplicity.

STOVES

The stove and the grate, two symbols of domestic peace, play an important part in the life of northern nations, so that as far as the clay industry is concerned in their production, it is worth while giving them special attention.

These stoves, whose primary object is the heating of the room, have at the same time been developed in their exterior to such an extent that they are often objects of ornamentation. They have been developed into a separate, distinct part of the house, and we see it at the exposition in many different exterior and interior constructions, so that special study is required to discuss it fully in all its details. For this reason I can give only a limited discussion of it. Of course it is only those areas in which the climatic conditions necessitate it, that this type of stove has had any remarkable development, namely, in Germany, Austria, and Sweden.

The rise of the ceramic industry in Italy in the 15th century was accompanied by the development of majolica work in Germany, applied to artistic stoves and mantles. The city of Nuremberg was for a long time the seat of a majolica stove industry, and even at the present day we find a great desire to imitate the old German types of Nuremberg stoves.

The clay stove serves first the purpose of absorbing the greatest possible amount of heat from the fuel by burning it in a proper manner, and secondly, it is constructed so as to serve as a reservoir for the heat thus evolved, giving it off to the air in the room slowly and not suddenly. Clay seems to be specially adapted for this last purpose owing to its slight heat-conducting power, and although the custom of heating rooms by steam, hot water, or hot air is often desirable on the ground of economy, at the same time the clay stoves still hold their place in the domestic economy of German family life.

The number of clay stoves shown at the exposition is very large, and amounts probably to several hundred, but it is difficult to compare them owing to the fact that instead of being placed near each other in the exposition they are scattered over a very great space, the different exhibits being more or less isolated.

We will begin with the German products, which probably rank first owing to their better construction as well as their more artistic decoration. The common custom in Germany is to cover the color of the clay with an opaque lead-tin glaze, or sometimes by a very dark-colored, translucent one. The former method is most used in the case of the white faience or porcelain stoves, while the latter is mostly employed in connection with the first, in stoves made after the old German style, the so-called art-stoves. The ornamental parts proper as well as the tiles themselves are richly decorated.

It is true beyond doubt that for the decoration or covering of larger surfaces, the white tin enamel glazes are specially adapted. At the same time they diminish the effect of the modeled surfaces and do not bring out the fine lines of the decoration so well as colored glazes, and hence we observe that for the ornamental stoves the old German style is coming to the front more and more. At the same time the unsatisfactory effects of the white enamel are more or less modified by the use of muffle colors and gold decoration.

Of the reproductions of old German stoves there are to be mentioned especially the products of C. W. Fleischmann, Nuremberg; Chr. Seidel, of Dresden; C. Teichert, of Meissen; Th. Lunz, of Nuremberg; and of the Keppler Stove Works, at Stettin.

The products of the Fleischmann Art Institute have acquired a reputation for some time. We meet them in the division of German house furniture in the shape of a rectangular, green stove whose tiles have medallion-like recesses, and are decorated with animal figures; they are glazed on a blue ground. A second Gothic stove, quadrilateral in the lower and decalateral in the upper part, represents partly biblical scenes, partly portraits of Jewish kings and judges. The factory of Chr. Seidel, of Dresden, which at the last industrial exhibition at Cassel exhibited a large grate stove in the manner of Lucca della Robbia and was awarded the first prize, is here represented by a similar stove; the dark green, finely mottled ground color of the stove is contrasted by a rich relief decoration which at the front surrounds a niche; the relief represents leaves and fruit and is colored with various enamel colors. The other sides of the stove consist of panels composed of very beautiful, gray, mottled tiles. A few other stoves made by the same firm are found in the furniture exhibits of the German division; of these there are especially prominent two stoves, one obelisk-like, decorated with a blue enamel in rococo style with relief fruit garlands in variously colored glazes, the other being a rectangular grate stove designed in the old German style. The latter is deep brown in color with recessed tiles which carry also small flower ornaments in green and blue glazes. Mr. Chr. Seidel exhibits a typical modern Berlin stove which is satisfactory in every respect. The color is a pure white, and the plastic decoration is reduced to a minimum. The frieze is smooth and decorated by white vines on a black background, the latter being burned on to the white enamel in the muffle kiln. An agreeable impression is produced by the sharp contrast and the beauty of the drawing. Th. Lunz, of Nuremberg, exhibits a large, green-glazed, old German stove; so does F. W. Schmidt, of the same city, decorated with portraits of living rulers. Both deserve praise for the technical execution and uniformity of color.

Of colored stoves there are also found a large drawing room stove by Schmidt, of Munich, enameled in blue and decorated with silver leaf ornaments. Finally there is to be mentioned a large old German mantel by the Stettin Stove Works, composed of brown glazed tiles with coat-of-arms and figures of knights. The latter are executed in matt enamel colors. A pleasing shading is produced by a transparent glaze on the brown modeled tiles and ornaments.

Special interest is aroused by the products of Villeroy and Boch, of Dresden, who are introducing a technique in this branch of the clay business, which, though not new, is eminently pleasing. The characteristics of the new technique is the molding of the ornaments as well as of the smooth panels of the stove tiles in a whiteware body, the back portion of the tiles being pressed out with a fire-clay body mixed with grog. In this way two results are obtained: first, the tiles are made much more resistant to sudden temperature changes; secondly, the thick tin glaze is replaced by a thin, colorless or faintly blue glaze without impairing the whiteness of the color. Of course the grain of the grog used must not be too coarse so that the stove tiles can be cut without difficulty. There is no doubt but that such a treatment results in sharper ornaments than with the use of ordinary enamels or in using a white engobe, and the tiles thus made are equal to the ware made by the Berlin, Velten and Stettin works. Yet it cannot be denied that the smooth stove tiles are inferior to the ordinary tin enamel tiles in beauty of exterior appearance. Perhaps a compromise could be effected by uniting the advantages of the two processes: the smooth, plain tiles could be made in the old way, using the old faience enamel, while for the ornamental pieces the whiteware grog body could be applied. Of course, this would introduce the difficulty of matching the colors, for it is a well-known fact that tiles which, examined separately, appear to be exactly equal in color, are found to show disagreeable color differences when put close together.

Of the stoves made in the style of the Berlin stove industry the Stettin stoves, especially, excel in beauty of glaze, and those made in Magdeburg by tasteful ornamentation. A grate-stove is especially prominent in which the pillars, consoles and arabesques are colored with a fine brown muffle color, while the details of the modeling, rendered somewhat indistinct by the heavy enamel, are brought out again more prominently by the use of a few dark brown lines following the stems and veins of the leaves. It cannot be said that the Berlin stove industry is represented in the most fitting manner; a white mantel-stove by the Berlin Stove Company decorated with painted wreaths of vines, blue grapes and wheat is almost ugly, owing to the extreme contrasts, while a stove with blue designs is more agreeable.

In general it may be said that the German products of the stove industry deserve all praise, and although they are not equal to the magnificent English mantels in which are used bronze, polished steel and expensively painted porcelain tiles, they still show much that is good and worthy of imitation. It may even be said that the technical side, especially the fine white and brilliant enamel, so free from crazing, stands unexcelled.

Although the German division is large it is exceeded in extent by the Austrian exhibits. As a whole, this division shows the same results as the German, the differences being found only in the variety of treatment and selection of the raw materials. While the faience glaze predominates in the German section the Austrian division contains many unglazed stoves in one or more colors, also bronze ornaments and colors produced by the use of engobes. Bernhard Erndt, of Vienna, exhibits some good reproductions of old German stoves in variously colored glazes and tiles with recessed panels and figures in majolica colors. Jos. de Cente, Franz Erndt, of Vienna, and J. Sommerschule, of Prague, exhibit single stove tiles in rococo style. Other exhibitors are Franz Diehl, Vienna; J. Ginzelberger, Vienna; B. Schadler, Linz; A Kummerer, Vienna; F. Schludermann, Villach; A. Samassa, Laibach; E. Dubsky, Wittenau; H. Jellinek, Pilsen, etc. Though these exhibits are pleasing in many instances, the fact remains, however, that the technical execution of the Austrian products is inferior to that of the German. This is especially true of the white enamel glazes which are all dull, rough or crazed.

The stoves seen in the Austrian section, which carry a white engobe over which is applied a transparent glaze, that are designed to replace the expensive enamel stoves, are a disappointment, since the glazes are always crazed and the details of the modeling are rendered as indistinct by the use of the engobe as by the enamel. At any rate the Austrian manufacturers will find it advantageous to follow the work of the North German and Nuremberg industry.

A very expensive stove is found in the Swedish division, made at Roedstrand, near Stockholm. It is a mantel-stove of large dimensions richly decorated by a niche surrounded by columns and beautifully modeled leaf and fruit wreaths. The body is apparently a whiteware composition glazed in the manner of the English majolica with matt blue, brown, green, and yellow glazes. The price of this piece, so rich in beautiful shapes and tasteful decoration, is 1500 florins.

THE BELGIAN AND DUTCH CLAY INDUSTRY

The Belgian and Dutch products exhibited at Vienna do not excel by the artistic treatment of the materials, but rather by their extraordinary high quality and the care taken in the manufacture. Both countries are represented by products belonging to the lower grades of clayware, and for this very reason they are of special interest, as they show how it is possible, simply by working the raw materials carefully, which may be found in other countries of equal or better quality, to produce ware that acquires for itself a reputation and sale far beyond the boundaries of the country. Belgium is represented chiefly by its refractory products, Holland by various products of the brick industry.

It is generally known that Belgium possesses a great store of excellent refractory clays, since in many German districts Belgian fire-clays are used. It also is quite evident that since Belgium consumes a large part of its refractory ware, owing to the great extent of its iron industry, it possesses a great number of large fire-brick works which utilize the vast deposits of fire-clays for the manufacture of refractory goods for the native as well as the foreign iron industry.

The Belgian refractory products owe their reputation not only to the high quality of the clay, for we have in Germany clays of equal or greater heat-resisting power, but in part to the prepossessing appearance of all of the products, in part to the density and exact shapes which have considerable bearing on the resisting power of the ware. As a leaning material there is used for the better products, fire-brick, shape brick for furnace linings, gas retorts, glass pots, etc., usually pure calcined clay, and it seems that more attention is paid to the sizing of the grains than in our German establishments. At least, even the non-technical observer may notice that while the German products are more or less porous and show a network of fine cracks on the surface, the Belgian ware has a perfect surface and a dense structure. This striking difference is to be ascribed not only to the high quality of the materials used, although the shrinkage relations are evidently of great influence upon the density of the body, but also to the use of proper sizes of grain. The various mixtures of sizes are adapted to the requirements of the different industries using them, and are also proportional to the amount of water which is used in rendering the raw material plastic. Of importance also is the care with which the pieces are repressed, as they become stiff, and finally, with which they are trimmed or polished. Though such careful work will raise the cost of production, yet experience shows that the appearance of the ware has a great deal to do with the selling, even though the quality may not be better than that of products from nearer markets.

Among the products of the fire-brick industry we mention those of De Lattre & Co., in Andennes, which are made from the world-renowned clays of Andennes, and gas retorts from the same firm; in addition, Smal-Smal & Co. show raw materials and fire-bricks for blast-furnaces. These bricks, as well as those exhibited by several other firms, and also gas retorts and pipes, 1 meter in diameter, all show the great care with which they have been manufactured, for on the surface we do not find a trace of a crack or projection. The fire-bricks, which are used for blast-furnaces and similar purposes, have on one side of their surface a semicircular groove of 1 cm. radius; on the opposite surface there is a corresponding ridge to fit into the groove of the next brick, the object of this being to produce a closely fitting wall with a minimum amount of mortar. It is, of course, understood that in order to make bricks of this type fit together closely, the greatest care must be taken in their manufacture to produce uniform shrinkage and equal sizes, and it is in this respect that the Belgian works are so prominent.

Of the other refractory products, such as gas retorts, zinc, and iron muffles, there are in addition to those already mentioned, the products of the St. Chislain Company, and the zinc works of Mr. de Lamminné, at Ampsin; the muffles of the latter are made on a newly patented press.

Of other kinds of clay products there is little or nothing shown, except an assortment of stoneware and white earthenware filters and jugs from the firm of Genotte, at Brussels.

What has been said of the Belgian clay-working industry, namely, that it is developed chiefly in one direction is true also in the case of the Holland industry, but in other directions; here we find the ordinary brick products. Holland has to fight continually the elements, its chief enemy being water, and this necessitates the use of a building material which will withstand its effects. In compensation for the almost total absence of natural building materials, nature has been kind enough to deposit around the mouth of the Rhine a great mass of material suitable for the manufacture of bricks.

The great care with which the Dutch brick industry is carried on is partly characteristic of the nature of its people and partly due to the existing conditions of that land; one thing is specially noticeable, and that is the great number of sizes and shapes of their products.

The damp climate of Holland and the resulting clays have probably been responsible for the use of small bricks and we see bricks in fully a dozen different sizes which vary from our ordinary size down to small paving bricks whose dimensions are 15 x 7 x 2.5 cm.

Among the exhibitors to be mentioned are H. C. Heukelom, of Utrecht, who makes machine bricks in sand molds. I have not been able to find out anything about the style of machines used, but it is stated that their daily output is 25,000 to 30,000. Sand-molded bricks are also exhibited by B. W. Von Calker & Zeist; A. R. De Lint, of Delft, has a rich assortment of bricks in all possible shapes, as well as roofing tile, and wall tiles burnt not only in the natural red color of the clay, but also, as is the common custom in Holland, colored gray or bluish black by blue-smoking and vitrification. The roofing tiles shown by F. L. Visser, of Workum, have invariably an S-shaped section like the ordinary Dutch roofing tile and are apparently homogeneous and well burnt.

The once flourishing industry of Delft ware, which was the first European imitation of the forms and decorations, but not of the bodies of Chinese and Japanese porcelain has, since the discovery of porcelain in Europe, fallen off considerably. The products of the one exhibitor, namely, Ravestejn Bros., of Westraven, near Utrecht, consist of wall tiles decorated in Chinese designs and with a glaze of high perfection; they are inferior to the better grades of similar wares of German and French manufacture, but still their decoration of sharp lines of blue and violet, as well as green and yellow, shows many features that are worthy of imitation.

THE GERMAN CLAY-WORKING INDUSTRY

The German division of the exposition is the one which next to the Austrian exhibit shows a complete picture of the ceramic industry, and is not confined to one or a few branches, as is the case with the English, French and Belgian exhibits. I have already spoken of certain branches of the German clay-working art, and I shall refer to them only to such an extent as is necessary to enable me to give a complete picture of the whole, and compare it with foreign manufactures in the same line.

Unfortunately the different exhibits are set up at widely separated points so that it is almost impossible to obtain a comprehensive idea of them in a short visit.

Let us take up first the high-grade products of the ceramic art, namely, the porcelains, and next to them the fine grades of whiteware.

Those pieces which represent the most skilful and artistic talent come, of course, from the royal factories at Berlin and Meissen.

These two plants have served as model institutions for the development of the private industry; they exhibit great ornamental pieces, such as are to be found only in palaces and whose execution in private works for a commercial purpose would hardly be possible; it is, of course, these magnificent pieces of ware which attract our interest first. The direction in which these two royal factories are working is by no means the same; in Berlin it is the decoration in color which gives to the work its special character, while in Meissen, on the other hand, the greatest care is given to all the details in modeling. While the position and support of the Meissen and Berlin factories has made it possible for them to employ the best talent in the lines along which they are working, at the same time we cannot deny that, aside from the masterpieces to which we have already referred, their work, as a whole, is at the present day no better and even not as good as that sent out from some of the private factories. This is especially true in regard to the factories of C. Tielsch & Co., of Altwasser, and Villeroy & Boch, in Mettlach. Although the last-mentioned factory uses a somewhat different mixture of clays than the previously mentioned establishments, and while its wares are to be classed as whiteware rather than porcelain, at the same time its method of decoration is very similar to that of porcelain. In the products of C. Tielsch & Co., we must admire the painting, the beauty and the variety of shape, and the luster of the colors, while the Mettlach works, which are so unique, that we have to examine them in detail. The Mettlach factory exhibits not only the greatest amount of ware at the exposition, but it, without doubt, shows development along the greatest number of lines; we find ornamental ware in all forms and decorated in many different ways, domestic wares of all kinds, wall and floor tiles of many different types, and terra cotta; with all this, the products are so different from those of the other factories that they possess a character which is at once distinct, and we are enabled to state their source at a glance. On the one hand they seem to be influenced somewhat by the English industry so that for an instant we are led to believe that they are imitations of imported articles, but, on the other hand, they carry such a distinct originality that we are obliged to look upon them as native products. The porcelains and stoneware articles which are shown by this factory are not inferior to any made at the present day.

Of special interest is the decoration of the Mettlach ornamental vases made of colored clays whose painting or plastic ornamentation is applied in colors. The means used in applying these decorations are sometimes so simple and bring out such rich results, rich not only in form but also in color, that they far surpass any other work. Still with all this elegance, there is a solidity of appearance to the whole thing which gives it an air of strength and durability. While the materials that we have mentioned are not true porcelain, at the same time the body is vitrified and consequently just as durable. Of special interest are the architectural objects of a white, porcelain-like body as well as in yellow and gray colors; such are statuettes, vases, medallions, Gothic terra cotta, and floor tiles, which are certainly the most durable products it is possible to make.

In addition to the porcelain articles mentioned above, others are exhibited by the factory of Carl Krister, at Waldenburg, C. Heckemann, and Rappsilber, in Königszelt, decorated domestic wares, Dressel, Kister & Co., of Scheibe, and Passau, Macheleidt, Triebner & Co., of Volkstedt, H. Kügemann, of Waisenau, and others, chiefly statuettes, groups, and bisque figures, as well as transparencies.

The whiteware establishment of Prince Ysenberg, at Waechtersbach, shows pottery whose decoration and beauty are such as to lead the layman to believe that he has before him Berlin articles; equally worthy of mention are whiteware objects such as toilet sets, jardinières, and vases in print-colors and painting. The whiteware pottery of B. Schaible & Co. is decorated in blue, which is put on the ware in a simple manner by means of a sponge, and is a product more for cheapness than beauty. In contrast to these we should mention the inlaid designs of the Sinzing Mosaic Tile and Clayware Factory, which, though they do not come up to the Mettlach wares of which they are an imitation, are deserving of praise.

The products of the porcelain and whiteware pottery of Uechtritz & Faist, in Schramberg, Wurttemberg, are also worthy of mention. The chief products of this factory are dessert sets covered with a transparent colored glaze applied over a white modeled surface in order to bring out greater contrast in the shading by varying the thickness of the glaze, a decoration practiced in England and by the Berlin manufactory. The motive of this plastic decoration depends partly on the use to which the wares are to be put; the designs are mostly leaf shapes, and the color of the green glaze being in harmony with them is often rendered more beautiful by shading into yellow and brown. This introduction of other colors renders the ware more beautiful than many of the English products.

The products of the more ordinary types of faience, that is, claywares having a colored body which is covered with an opaque tin glaze, have already been mentioned by me. This type of decoration is especially common in France and Italy, as I have previously explained; in Germany it is used chiefly in the manufacture of stoves as imitation of porcelain.

By this means many works have succeeded in covering large surfaces in such a manner that the color and the luster are similar, and sometimes even superior, to those of hard porcelain. At the same time in their desire to prevent any thinning on the part of the glaze and thereby allowing the coarse color to show through, the result has been that they coat the body more or less thickly with the white enamel, and this covers the fine details of modeling. When we compare the products which were exhibited at the Cassel exposition, with those now shown at the Vienna exposition, we cannot help but see that a great step forward has been taken, and that we find a greater degree of perfection in the use of colors in place of the cold white which was formerly so prevalent.

Household pottery, especially stoneware, is rather incompletely represented. Of special interest are those salt-glazed wares from the region known as the "Kannebaeckerland," which are not only very durable, but also rather remarkable for their decoration, usually executed in blue and black.

The mugs exhibited by F. W. Merkelbach, from Grenzhausen, are, in part, of old Rhenish design, and decorated with a brown and blue glaze; they are to be reckoned among the more artistic products of the region mentioned above. The chemical wares of B. Merkelbach, at Grenzhausen, and of Knödgen, at Baumbach, as well as others, have won a wide reputation on account of their durability.

Very pretty reproductions of old-fashioned pottery (drinking-mugs, etc.) in rather tasteful shapes, and covered with paintings and inscriptions, are exhibited by A. Sältzer, of Eisenach; in the same class belong also the old style mugs from the Fleischmann Art Institute of Nuremberg. Wares of all kinds, and common pottery with a good, light yellow, interior glaze of excellent appearance are shown by the firm of W. Lampe & Co., of Wittenberg, together with Bunzlau ware made by Lepper and Kuettner, of Bunzlau, and C. Dretwa, of Muskau, which are decorated with white and colored flowers and animal figures. The clay works of v. Levetzow, at Kiel, exhibits a very rich collection of flower-pots in plain, as well as modeled, surfaces; also some painted with oil colors.

Among the terra cotta and ornamental bricks we find much that is beautiful and worthy of imitation. The great demand for exterior decoration is shown by the large number of factories which have gone into the production of terra cotta ornaments. The reputation of such factories as E. March & Sons, of Charlottenburg, the Augustin brick-works, at Lauban, is well known, and the products made by these two works are so prominent in their line that it is really not necessary to compare them with other ceramic productions of this nature. The exhibits of these firms are the finest in this branch of ceramic work, and should have been made more prominent.

Next to these there are many other products which, while not perhaps so well executed, at the same time are of sufficient merit to be considered here.

Among these are the products from the Greppin clay-works, the different forms of which are put together in a large ornamental structure containing a wall with many niches and crowned by a row of columns. The pleasing yellow color of the material is in places relieved by the insertion of dark-colored bricks, especially those which are made from leather-brown and blackish brown clay, the former being produced by a very thin dull glaze, the latter color being brought out by an engobe of fusible ferruginous loam. The Dithmer clay-works show an interesting assortment of articles. Among them is a large selection of glazed and unglazed ornamental and pressed-bricks, which are of interest, not only on account of their colors but also on account of the quality of the glaze, one handsome set being of a fine gray color. Whether the color of these bricks is natural, or whether it is produced artificially, cannot be determined from the mere inspection of the product, but certain streaky colors shown on some of the pieces lead us to think that it is done artificially in perhaps a similar way to that practiced in blue-smoking, but using a calcareous clay. At any rate the color is very beautiful and worthy of the attention of architects.

Another style of decoration is to be observed in the very hard products of the von Raumer factory, near Hirschberg. The animal figures exhibited, besides ordinary bricks, are peculiar, owing to the presence of a superficial coating burnt on which is so regular that the supposition is suggested that it might have been produced artificially.

The refractory materials exhibited in the German division are by no means small in amount, and we cannot judge them by a mere inspection. We hope, however, that this subject will be treated in detail later by a competent person.

Among the things exhibited are gas retorts and large refractory clay bricks from the factory of H. I. Vygen & Co., of Duisberg; the fire-bricks, which are also exhibited by this firm, show a remarkable density and a noticeable smoothness and sharpness of surface which we usually observe only in the Belgian wares of the same type.

Similar exhibits are shown by F. R. Geith, of Koburg, which include retorts of large dimensions, muffles and fire-bricks, all of them showing the mark of hard burning.

In addition to the great number of fire-brick factories whose wares do not show anything of special interest, there are exhibited some crucibles of refractory clay made by Gundlach & Bros., in Grossalmerode, also by S. Saxinger, of Obernzell, and F. Kaufmann, in Hafnerzell. This type of ware has found extensive use, and is shipped long distances.

Silica or dinas bricks which in recent years have been used in England for furnaces, in which the highest heat is developed, have also been introduced in Germany, and mark a new step in the industry producing refractory materials; in fact, they are already indispensable in the steel industry. Those made by R. Keller, of Stollberg, are produced from a refractory sandstone and, according to the investigations of Dr. C. Bischof, of Wiesbaden, are fully equal in refractoriness to those made in England. Two other factories show similar lines of work.

Note on the Brick Industry of Northern France

ALBERT BLEININGER, B.SC., TRANSLATOR

Nearly every country has its peculiar methods of manufacturing artificial building material. This difference in the methods of working is attributable not only to the variations in the properties of the raw materials used, to the peculiarities of construction, and the size of the brick, but in part to certain customs practiced by the workmen and handed down from generation to generation. On comparing the various practices customary in the different European countries in the molding, drying and burning of bricks, we find that some manipulations appear very advantageous in one place, while they are entirely out of place in other localities. Although the methods of one location cannot at once be transferred to another place without danger of failure, still it is well worth the trouble to become acquainted with such differences in method, and it remains for practical experience to determine whether or not such changes are advisable.

The methods of working in different German, and also foreign, brick districts, their advantages and disadvantages, as well as the amount of work accomplished by the workmen, have been repeatedly described. This time we shall examine the conditions prevailing in one of the larger French brick districts, the one along the lower Seine, between Rouen and Havre. The raw materials worked here are as different in two respects as they could possibly be, and yet they are treated in the same way in molding and drying; a difference is found only in their burning. The one kind of brick is a clinker, which corresponds to the highest requirements in regard to good shape and absolute vitrification. For this class of ware the raw material used is a clay very high in iron deposited on a plateau following the banks of the river, alternating with strata of flint. The bricks made in a number of brickyards are used almost exclusively for foundations and the extensive harbor improvements. As to the second material it may be said that it is a kind of silt deposited by the sea in great layers; it is used in most brick plants; physically, it is extremely fine, mixed with larger shells only occasionally, and it represents probably the leanest and most calcareous material which has ever been used in the brick industry.

In order to obtain a conception of the character of this material its analysis is quoted:

	Per cent.
Fine mineral dust, size of grain 0.01 to 0.20 mm. consisting of quartz splinters and infusorial earth,	52.7
Clay substance below 0.01 mm. size of grain,	16.0
Carbonate of lime, extremely fine,	31.3
	100.0

However, the composition is not constant, for the mass contains in another part of the deposit only 27.7 percent of calcium carbonate. Owing to the high content of calcium carbonate and infusorial earth the bricks are very light and friable; the weight of the bricks which possess a fine lemon color is only 1.7 to 1.8 kg., the dimensions being 21 x 10 x 6 cm.; the red-brown clinkers of the same size weigh 2.5 kg.

The green bricks made from these materials are sharp-cornered and nice in appearance, indicating careful handling. This is explained by the method of molding, which is both rapid and neat, as well as by the fact that the bricks are small in size, which renders manipulation much easier. The tools used by the brick-molder of this district are different from ours. The molding table has about the same dimensions as ours; on it is placed the prepared clay. In front of the molder there is a block about 3 cm. high, which is plated with iron, and which possesses such dimensions that the mold, made from iron plate about 3 mm. thick, can readily be drawn over it; at the four corners of the block four nails with square heads are driven in the table so that the block projects into the mold about 5 mm.; the mold rests on the heads of the nails and the block forms the bottom. In addition there are required 100 to 150 planed boards, 25 cm. long, 12 cm. wide and 1 cm. thick, made out of hard wood, and a wooden box containing the fine clay powder or ash necessary for dusting the mold. The manipulations of the molding are now as follows: The workman cuts off a suitable lump of clay from the pile, rolls it on the dusted table into an oval shape and throws it into the mold with all his might, striking off the excess of clay with his hand. He then removes the mold, whose long side he faces, by a rapid movement and hands it to a boy while it still contains the brick. The helper at the same time places a freshly dusted mold over the block. While the molder prepares a fresh ball the boy places a board over the mold and, turning it over, draws away the latter. The brick on the pallet is carried or wheeled to the drying racks.

The clay used in molding is prepared by means of the pug mill so stiff that the bricks can at once be hacked on edge; where the off-bearers are somewhat practiced they can set the bricks two courses high without injuring them. In most cases the bricks are dried in racks under roofs. The bricks are not dried on the small pallets, but twenty-five to fifty bricks, on edge, are dried on one long board. To these boards there are nailed short pieces of stout board, 14 cm. high, dividing the boards into lengths of 1.25 meters, the shorter boards making two, the longer four, divisions, of which each will hold twelve to thirteen bricks on edge. The hacking proceeds as follows: First a board is put down on the ground, supported by some bricks, and is placed crosswise in the shed, the cleats nailed on being on top. The bricks are now placed on the board by being allowed to slide from between the two thin and smoothly planed pallets by means of which they are taken to the drying shed. In this way the bricks are placed on edge. As soon as one drying board is filled a second one, also with the cleats on top, is placed on it; this is continued to a height of twelve or fifteen boards. Since the cleats are 14 cm. high there remains above the bricks an empty space of 4 cm., and as much between the bricks. In this manner the entire shed is filled without leaving any alleys, a space of 10 cm. only being allowed between the boards for the admission of air.

It cannot be denied that this method of setting causes the brick to dry very slowly, but, owing to the small size of the bricks and the violent gales from the sea, this procedure offers some advantages, since room is economized and the work concentrated. Only in rare cases are the bricks set directly in hacks after molding, and where this is done the piles are increased only by one row of bricks per day. Occasionally the bricks are dumped on the ground, using sanded double molds; but since the bricks are used for facing, and since deformed and rain-washed bricks do not bring a good price, this is not practiced very extensively. The molding and drying is, as a rule, done by piece work, the price paid being 8.50 to 9 francs, including all the work from digging the clay to placing the dry bricks in tight piles under sheds. A molder makes on the average 5,000 bricks a day when using a single mold; when a double mold is used 7,000 bricks are made.

The burning is, as a rule, done in clamps, a continuous kiln being used only in one yard in which each compartment holds 30,000 bricks. Where the continuous kiln is employed 130 kg. of Scotch small coal is consumed for burning a thousand bricks. The buff bricks also, with one exception, where a continuous kiln is employed, are burnt invariably in permanent up-draft clamps holding from 50,000 to 200,000 bricks. The kilns are square, open on top, and are provided in the bottom with a number of permanent flues covered by perforated arches. The firing is at first done with wood, and later, when the flues have become red hot, with lump coal. The dimensions of such a kiln are: Length, inside, 15 meters, width, 8 meters, height, 6.5 meters; eight firing flues, arranged crosswise, 80 cm. high and 60 cm. wide. The flues were fired from both sides and are divided in the middle by a thin wall. At the mouths of the flues square wrought iron bars are fixed at an angle of about 30°, which are supported by an iron rod on the outside and touch the ground on the inside. There are no fire-doors, the furnace mouths being kept filled with coal. The bricks are covered on top by a double platting without openings for the regulation of the fire. As is to be expected the consumption of fuel is very high, 260 to 280 kg. of lump coal per thousand, not including the wood used in water-smoking. The output of bricks also is very irregular, they being divided into three grades, according to color, cracking, etc.

Beside the common bricks, paving and roofing tiles are produced in large quantities, especially the first. These are made from a mixture of a plastic, calcareous clay and a red burning material. The one point worth mentioning concerning these products is that they are considered good only when flashed yellow and dark red in burning, this being the only case known to me where irregularity of color is intentionally produced.

Paving tiles as well as the roofing tiles are either molded by hand, or by means of the machine. When in the stiff condition they are repressed in screw presses whose dies are lubricated with oil or petroleum; the ware is set when still green in order to facilitate the flashing of the surface. The roofing tiles are slightly curved so that on the roof their surface does not touch the tile beneath, since the edge alone is in contact with the latter; this is intended to prevent the admission of water through the fine capillary slit. Usually the roofing tiles are not repressed, but are curved, when stiff, over a pattern, since the repressed tiles are justly considered less weather-resistant than the hand-molded ware.

Reports from the Paris Exposition 1878

ALBERT BLEININGER, B.SC., TRANSLATOR

The sight offered by Paris to the industrial world is so grand and overwhelming that it is difficult to form an estimate of the achievements and the progress of the industries, after a stay of only a few days. For this reason I must confine my report of to-day to describing the first impressions made by the exposition on the visitor, and I shall in my later reports refer particularly to the achievements of the clay industry.

The exposition palace proper is located on the Mars field, and is a gigantic structure of glass and iron 600 meters long and 300 meters wide. The main front with the entrée d'honneur faces the Seine at the Jena bridge. The wide space between the palace and the Seine is filled with gardens in which are found restaurants, the pavilions of some countries, and separate large establishments. On the other side of the Seine the terrace-like space up to the Trocadero palace with its fountains has scattered over it the Orient with its coffee houses, bazaars and fantastically cloaked inhabitants. On the north side there are the French colonies and a number of smaller pavilions, most of them devoted to engineering. The great rectangular exposition place is closed to the west by the Trocadero, containing the ceremonial halls, the meeting-halls of the international congress, and the art collections. From here a magnificent view of the exposition place is enjoyed. On both sides of the main building surrounded by gardens, there are larger and smaller pavilions devoted to separate industrial branches or countries and arranged as a whole so as to be continuations of the main exposition hall.

The French exhibitors occupy fully one-half of the total available space, while the remaining part of the world must be contented with the other half.

The main hall is divided along its main axis by two aisles into three parts. Between these aisles the artists have found their home, and here Germany is fittingly represented, while, as is known, German exhibitors are not taking part in the competition. Any one who has studied the exposition will regret this fact.

On entering the palace from the Seine, on the left of the fine arts hall there are found the French exhibitors, on the right the foreign, whose exhibits on both sides are closed by the machine halls of the respective countries. The French part forms, of course, a complete whole, while the foreign exhibits are so arranged that passing down the length of the building each industry forms a section in which the different countries are represented in the following order: England, United States, Scandinavia, Italy, Japan, China, Spain, Austria-Hungary, Russia, Switzerland, Belgium, Greece, Denmark, Central America, Anam, Persia, Tunis and Morocco, Luxemburg and Monaco, Portugal, Holland. On crossing the building, at right angles to the longitudinal axis there are always met the separate industries of the same country.

In spite of the enormous difficulties of such an immense undertaking, in respect to the proper arrangement of the various exhibits, it must be said that the exposition is well planned. The fact that the French industry is numerically most prominent, does not suffer by the arrangement, and possesses an imposing character is due, in part, to the activity of the French manufacturers, and partly to their ability to arrange their exhibits tastefully and effectively. Without such a regularity of arrangement it would be impossible to locate points, for the Paris exposition is not only being visited by more people than the one at Vienna, but also the number of exhibitors is greater and the exhibits are more extensive.

Although Germany, with the exception of art, is not actively represented at the exposition, it is interesting to note that the Germans are taking pains to recover from the defeat suffered at Philadelphia and are trying to learn; the German language, outside of the French, is heard most often.

On entering the exposition the strong representation of the clay industry, especially of the faience and porcelain branches, becomes at once evident. It has largely aided in furnishing the means of decoration for the exposition in all its parts, and this is a proof that the French clay industry is highly developed, so that our manufacturers are given a fine opportunity to acquire valuable information. The French faience, represented by more than a hundred exhibitors, is shown not only in great pieces all over the exposition, but every façade glories in enameled faience, so that the latter gives to the whole a characteristic appearance. In fact, no artistic industry has made such rapid strides since the Vienna exposition than the French art pottery. It meets the visitor's eye at every point, and makes known to him that in this branch France has taken the lead over all other European nations, and has challenged even the old pottery-producing countries, China and Japan. Also the so-called common ceramic branches, producing ordinary bricks and pottery, are so richly represented by raw materials, products, and machines that they offer much material for study.

Brick Products and Brick Machines

As has been said, the French products are represented especially strong, while the other countries seem to be more in the background than at previous expositions. It is in the nature of the case that this is still more true of the lower products which are not worth the trouble of being transported long distances, for the prime incentive is not only the honor to be expected, but more so the chance of obtaining wider markets for the manufacturer. For artificial building-material the market is circumscribed by a rather narrow limit, and when, hence, we speak of brick products at the exposition we can mean only French goods. Although a few foreign exhibitors show building and fire-brick products, these are but the exception, and are restricted to some specialties like the Belgian gas retorts, fire-bricks, English blue bricks, and Schattau and Pest paving brick.

The French brick products are well represented, and this is mostly due to the efforts of a society, the Union Céramique, which is identical in purpose with our German Clay Workers' Association. This society has furnished, in a special pavilion, a very instructive arrangement of brick products which, in connection with the products of other exhibitors in the different smaller buildings devoted to engineering, give a good representation of the French brick industry as far as an exposition can do this. It cannot be our task to describe the products of every exhibitor, as this would be too tedious, but a general résumé might be of some value.

The French brick industry, as a whole, is governed by entirely different conditions from the German, especially of Northern Germany. France is rich in natural building stone, and, especially in Paris, the consumption of artificial building-material is relatively small. The chief building-material of Paris is a coarse limestone quarried in the vicinity, and no face-brick or terra cotta fronts, such as we have, are found. In the provinces also brick fronts are scarce, even where natural stone is hard to work, and hence expensive. An interesting example of this is the city of Limoges where the fronts are almost exclusively gray granite without any ornamentation. Bricks are but seldom used in fronts, and then always in connection with limestone or sandstone, which furnishes the ornamental part.

This explains why the front brick and terra cotta industry is but weakly represented in France. On the other hand, the construction and arrangement of the French houses has had a tendency to develop the brick industry in another direction. The exclusive use of grates in houses, the use of floor tiles, even in the upper stories, and the customary roofing with tiles offer other fields to the clay worker. The manufacture of hollow bricks and chimney pipes, of interlocking and decorated roofing tiles, garden ornaments and paving tiles represents the activity of the brickmaker, while the ordinary building brick where needed is made in very primitive brickyards; the number of yards employing continuous kilns is a very small one.

One peculiar fact noticed, which certainly is not accidental, is, that for the different products different raw materials are selected, and it seems that the properties of the clay are considered more carefully than is the case with us. The hollow bricks, which are extensively used for partitions and other light walls, are made almost exclusively from a very plastic fire-clay, and are burnt to a density, which is observed usually in stoneware. For this reason the walls of the brick need only be very thin, and the bricks in spite of their great strength are very light.

None but red-burning, well-vitrifying clays are used in the manufacture of roofing tile; no porous roofing tiles made out of white-burning fire-clays or marl are found. Even in ordinary brick and pavers, as well as garden ornaments and pipes, the dark red color predominates everywhere, while the buff and light burning clays are used but little.

Among the brick products, only the interlocking roofing tiles deserve special mention, since these are being introduced in Germany more and more. The shapes of these tiles, subject to some variations in the different establishments, are those known to us, although the dimensions are usually somewhat smaller. This is due probably to the decreased difficulty of making the smaller sizes. There are, however, exhibited some very large sizes up to a length of 0.75 meter and a width of 0.5 meter; these pieces are presumably shown only to indicate what can be done along this line.

Although some of the interlocking roofing tiles are glazed with colored lead glazes and tin enamels, most of them are unglazed; at the same time they possess, however, a certain luster which is due to the manner of manufacture. While in Germany interlocking roofing tiles are usually pressed in plaster molds, which are readily injured, and hence give rise to rough-looking tiles, the French establishments use almost exclusively cast-iron molds. This is confirmed by a look into the machine hall in which quite a number of roofing tile presses are distributed; among them there is not a single one working with plaster molds, but they all are provided with molds of polished cast iron. In order to use these satisfactorily it is only necessary to lubricate every clot of clay before bringing it into the press; this is, as a rule, accomplished with a mixture of mineral oil and soft soap. In this way the tiles are easily removed from the mold and they possess, after pressing, a certain gloss, almost a polish, which is partially retained after burning. This method of lubricating is much more satisfactory than the oiling of the mold. Among the new shapes of roofing tile there are to be mentioned those provided with nail-holes for fastening the tiles to the roof exhibited by Dumont, at Roanne; another new style is represented by tiles made according to the system of Maingault, at Melun. The former in their upper part, covered by the next higher roofing tile, have one or two button-like projections, each of them being perforated, allowing the nailing down of the tile and yet preventing the rain-water from penetrating through these nail-holes.

Among the machines used in the manufacture of bricks we find, beside many old acquaintances, a few interesting new things. Boulet frères exhibit a number of pugging and molding machines which are remarkable for their strong construction. These are double and single rolls which are either plain or corrugated. This arrangement is not only intended to crush the clay more thoroughly, but it is supposed to do more or less pugging. Chambrette Bellon, at Béze (Côte d'or), exhibits, besides machines for the manufacture of interlocking roofing tile, also such removing stones and lumps from clay. The machine consists of two strong iron cylinders closed by plates, and so connected that they are turned about a joint shaft. The shell of the two cylinders consists of heavy iron plate perforated with holes about 5 mm. in diameter, so that it appears like a screen. While one of these cylinders is filled with soaked clay through the upper opening the other cylinder filled with clay occupies a position just above a piston, tightly closing the lower opening, the piston being moved upwards by a hydraulic press. The pressure causes the clay to escape from the openings of the shell in fine threads; these are removed and made up into balls. The stones are carried along by the piston, and after opening the top lid, which is fastened by strong bolts, they are ejected. After the descent of the piston, the second cylinder now filled with clay is moved above the piston and the same process is repeated.

According to the data furnished by the manufacturers a larger machine of this type, whose hydraulic pump is moved by steam power, and which requires two horse-power, can prepare 24 cubic meters of clay per day. The price is 3000 francs; a smaller machine, whose pump is moved by hand-power, costs 800 francs.

The same manufacturer exhibits a brick machine which very likely will prove new to most of our readers, although of late it has been praised as being the *ne plus ultra* in regard to capacity. This is a brick machine made according to the system of A. Allemand. It consists of a horizontal molding table, driven by gearing, around whose circumference there are sixty molds. The molds are closed below by plates which run by means of rolls on a circular inclined plane and thus are raised and lowered. At the place at which the bottom plungers of the molds occupy the lowest position there is a heavy conical roll which runs on the molding table, being rotated by the latter. Directly in front of this roller there is an iron box filled with clay. The clay is forced by the roller into the mold. The rolls, as well as the molding table, are scraped by means of knives, and the molded bricks are gradually raised as the table rotates, so that they may be removed before they arrive at the charging box. The capacity is said to be 2,000 bricks per hour, requiring only two horse-power, which certainly would be a most remarkable performance. There is to be considered, however, that the machine can work only prepared clay, so that some pugging machine must be used.

Just how the machine will work under practical conditions, and what clays it will work most efficiently, must be proved by experience; so far the results in most cases have not been especially favorable.

A very practicable movable repress is being exhibited by A. Chevalier and Bouju, of Paris. This differs from the represses commonly used in the fact that the molding box, as well as the pressing plunger and bottom plate, is movable, and hence a pressure is exerted, not only upon the upper and lower surface but also upon the sides. For this purpose the mold is divided diagonally, and the two halves of the mold, forming an angle, on lifting the repressed brick separate a few centimeters, so that the brick comes from the mold without rubbing on the sides. After placing in position a new brick to be repressed the halves of the mold first come together and press the brick from the side before the pressure between the upper and bottom plate is applied. The motion of the press is being produced by cams, as in the Clayton and Goerlitz machine; the pressure is produced by a lever and weight.

A great number of machines to be used in the manufacture of bricks, and similar products are exhibited by G. Pinnette, at Chalon sur Saône; they show especially some presses for making blanks for flooring and roofing tiles, as well as a large pipe press. Among the roofing tile presses we observe two systems. In one system introduced in Germany by Schmerber Brothers the movement of the upper half of the mold towards the lower half, moving in a guide, is caused by a screw which is given a forward and backward motion by friction disks and a heavy fly wheel. The clay blanks are made in a special press. In the second system, representing a smaller capacity (2,500 to 3,000 tiles in ten hours as compared with 3,800 to 4,500), the making of the clay blank and the pressing of the tile is done by the same machine. The blanks are made by a box press which forces the clay out of a die by means of a piston moved by an eccentric, the blank being about 3 cm. thick. The two halves of the iron mold are connected at the short side by means of a hinge, and rest on a slide which is directly beneath the press box. The blanks, after they are lubricated on both sides, are placed between the molds and slide beneath the machine where the pressing is done by an up-and-down motion. After pulling the mold forward the upper half is first turned up while the lower is opened by a second hinge at the side, the pressed roofing tile being thus placed on the drying pallet. The first machine costs about 3200 francs, a blank press for 10,000 tiles costs as much, while the latter machine, complete, is offered at 3500 francs.

The exhibit of Joly, of Blois, is worth noticing, owing to the number and variety of machines shown. Among the machines, which are sold in great numbers, are the presses used for making drain tiles, and blanks for the making of interlocking roofing tiles. These are provided with two horizontal shafts, carrying knives in a cylinder of oval cross-section. This is a combination which has often been recommended, and it has been used in peat-molding machines, but never, as far as known to me, in clay-preparing machines.

Besides the machines mentioned, there are quite a number of manufacturers who exhibit machines which offer nothing new in their construction and have been known for a long time; such are the Hertel press and the semi-dry press of Durand and Marais.

Foreign countries exhibit no brick machines with one or two exceptions; in the English division there is a Whitehead drain tile press, in the American a semi-dry press by Gregg.

The brick kilns and dryers exhibited partly by models and partly by drawings do not offer anything new to the German visitor. The French inventor in this direction apparently seems to endeavor to offer to the industry something which will excel the continuous kiln in regard to economy and the quality of the product. However, it is only necessary to glance over the proposed constructions to observe that these endeavors are fruitless.

To these attempts there belong the kiln of Chopin with a movable arch, the Dueberg kiln with a movable furnace, exhibited as an American kiln, the Simon kiln, very similar to the continuous kiln, with fixed fireplaces beside the doors for the purpose of water-smoking, and one at the head walls for starting the fire, and the kiln of Virollet with grates across the entire width of the kiln fired through an opening in the arch. But the most wonderful example of a combination kiln and dryer is the kiln of M. Curot, which certainly is the most complicated affair ever produced. It is a two-story tunnel kiln of which the upper story is used for drying, the lower for burning. The loaded cars are transferred from the dryer to the kiln by means of two elevators. The burning, as well as the drying space, consists of seven tunnels arranged side by side; between the second and third a smoke-collecting flue is arranged. The tunnels are provided with tracks and are connected by means of transfer cars at the two ends of the kiln; the cars loaded with the ware are supposed to pass through the seven tunnels one after the other. The train of cars is moved by means of a winch and gearing just as in the old Bock tunnel kiln. The firing is accomplished by means of grate furnaces arranged along the side of the tunnel; the second story in the model exhibited is not provided with any fireplaces, so that it appears that the drying is accomplished only by the radiation of heat from the lower to the upper story.

WALL AND FLOOR TILES

Of all the products of the clay industry exhibited at the Paris exhibition, none arouse our interest so strongly as the faience wares, and among them especially those which are intended to protect and decorate the wall. The quantity and quality of this sort of ware produced by the French manufacturers is so great that it surprises even those who are supposed to be intimately acquainted with the manufacture of French faience.

Up to the present, England possessed the greatest reputation in this respect; however, on examining the exposition buildings which are richly decorated with enameled tiles and their great faience mural paintings, one is bound to be surprised in regard to the great advance made by France since the Vienna exhibition, where it had just begun to devote more attention to this industry. It has not only equaled, but excelled England, though the latter, till lately, has been considered the most advanced country.

That the growth of the French faience industry is a natural one, and has not been accelerated artificially for the purposes of the exposition, is demonstrated more by the decoration of the buildings than by the products exhibited by the manufacturers. This also demonstrates that the industry possesses well-trained artists and workmen, and also that the French architects know how to use faience. In fact, there is hardly one of the many small buildings which does not possess colored enameled tiles, be it for interior or exterior decoration. At the same time the technical treatment is so many-sided and various, the means made use of so simple, and hence the execution so sure and complete, that the eye is never tired by the great amount of faience. This cannot be said of the other parts of the exhibition, not even of the English division, and only occasionally one finds wall tiles. In the oriental buildings, in which wall tiles are indispensable, they appear weak and crude compared with the French products; in many cases there are observed imitations of wall tiles in paper or paint.

Whether this exceedingly rich decoration of colored, glazed clay tiles can be justified from the artistic, architectural standpoint or not, must be decided by more competent judges; at any rate, this condition is extremely interesting to the ceramist, and especially so to German clay workers, where the clay industry is likewise being led into the same condition.

The main buildings of the exposition may be considered as being structures of iron, glass and faience. The long stretched halls covered with glass and forming a single connected building, consist of iron construction, supported by strong iron pillars, quadratic in section. The large smooth surfaces thus produced are faced on the outside with glazed tiles which give some life to the cold iron surface.

The decoration is formed of three rows of tiles joined together which, together with tiles decorated in high relief, form a rising ornament about 0.6 meter wide and consists of wreaths of leaves and birds.

The glazes applied are either opaque tin enamels, or, in part, transparent, highly colored glazes with brilliant luster, showing blue, red, and green on the bodies of birds appearing in high relief, and different shades of green, turquoise-blue, yellow, cinnamon-red, and brown on the leaves and blossom ornamentation.

The faience decoration of the main building is made by

Emile Mueller, of Ivry, enameled by Léon Parviller. The latter has done some remarkable work in another place, where he shows the scope of his technical power. This is a wall tile in the building of the French tobacco factory, which shows all variations of technical treatment permitted by faience. Representing an elaborate arabesque, it shows the richness and the brilliancy of its colors and the variety of its application. The colors, in part, are transparent, and in order to prevent their running together, the contours are outlined by painting with an infusible, probably clayey, mass high relief lines; this is a technique which we find frequently in other faience work. The plastic decoration and the shading of colors are produced in part by relief, and in part by incised, modeling on the body so that the varying thickness of the glaze causes light and shade effects. Relief-like tin enamels and colored pastes are frequently observed. The piece in question shows also a technique which is supposed to have been originated by Th. Deck, but which seems to be used by this manufacturer for other than architectural purposes, namely, the gilding of surfaces under colored glazes, through which these assume a peculiar metallic gloss and brilliancy of color, such as we observe only on the Limosine enamels on a metallic base.

In a style no less powerful, but without plastic treatment, and remarkable for the great simplicity of the means employed, as well as the perfection of technique, are executed the door and window trimmings and friezes made by Jules Loebnitz for the building of the fine arts, the pavilion of the Creusot iron works and others. The leaf decoration is applied only in a few colors (white, brown and green) on large surfaces, which are seen from quite a distance. The individual parts are outlined by an incised line, several millimeters wide, in order to prevent the colors from running together, and to bring out the color differences boldly. Closely inspected, the body color is seen as a narrow line separating the different surfaces, while from a distance the different colors offer a sharp contrast. The tiles are made from a buff-colored clay, not too fine in texture, and are 0.6 meter square.

The most imposing mural paintings are two large landscapes in the pavilion of the city of Paris, each being about 5 meters square. One of these was made by Th. Deck, of Paris, the other by Boulenger, Choisy-le-roi. Since the designs are made by the same artist, Jaeger, the two paintings permit of a comparison of the techniques, which, without doubt, is in favor of Deck. His technique is peculiar, differing radically from all others. His body is a fire-clay mixed with sand or grog of uniform grain, which is burnt hard and coated with a white engobe, which softens in the fire so that it is almost non-absorbent, but has no gloss. Such tiles, burnt hard, are put together to form larger or smaller surfaces, and serve as the background for the artistic work. As to the painting, Deck's products are not restricted to a single technique, but he chooses the one he needs for certain light and color effects; he uses relief-like, colored clay pastes and enamels, transparent glazes with raised lines, unchanged or flown, painting on the unburnt glaze in the manner of the Italian majolica, and underglaze colors on the clay body. At the same time the colors have a liveliness and delicacy as they are not found on other products. Beside a number of mural paintings at various places of the exposition, animal and plant groups, Deck cultivates especially the manufacture of Persian and Moorish wall tiles.

Beside the large painting of Deck the one by Boulenger, which is equally as large and similar to it in design, shows neither the fresh colors of the former nor the delicate shades and the technical perfection; the Boulenger works evidently use the ordinary white faience body. The products exhibited by E. Collinot, of Boulogne, are peculiar, and show perfect technical execution. The wall tiles imitate almost exclusively Persian designs and are painted either entirely with underglaze colors or colored paste, or the ornamentations are carried out in relief and are then usually unglazed; the deeper ground, however, is covered with colored tin enamel. The same manufacturer cultivates relief painting, especially on larger wall tiles, using plant and animal groups with birds and butterflies in his designs, indicating a Japanese taste which at present finds favor in Europe.

The several parts of the painting, the animal groups, flowers, birds, etc., are usually surrounded by a black line, and are made of a tin enamel, applied relief-like, which is prevented from flowing together by the contour line, and thus represents the objects by a sculptural effect. The colors are applied on this thick enamel either in the unburnt condition, or as muffle colors, which are applied and burnt after the fusion of the enamel.

Among the many kinds of wall tiling shown in the exposition building whose manufacturers, in many cases, could not be determined, we find many oriental designs which produce a variety in color, in part, by painting, partly by raised or recessed molding, thus varying the shades by thicker or thinner layers. Occasionally we find also plain, smooth and white faience tiles on which the colored underglaze designs are applied by printing or by the use of stencils. Among the number of exhibitors of faience in the French division (almost a hundred), we find very many who show, beside pottery and tile for domestic use and decoration, wall tiles, with painted or printed designs on fine or ordinary faience bodies, carrying a tin glaze. Foreign exhibitors also show products of this kind, especially Spain and Italy, which, however, consist mostly of painting on an inferior white tin glaze.

The firm of Boch frères, at La Louviére, has made an attempt worth noticing to produce wall tiles after the manner of the old Delft ware. The firm of Villeroy & Boch shows some excellent wall decorations with inlaid colors in the Luxemburg division.

As was to be expected England was likewise represented by wall tiles, and though the number of exhibitors was much smaller than in the French division, the quantity and the richness of the designs were extraordinarily large. The main exhibitors are the firms, Minton, at Stoke-on-Trent, Minton & Hollius, Craven, Dunnill & Company, at Jackfield (Shropshire), and Maw & Company, all firms which are well known in this branch of the industry.

In the manufacture of floor tiles governed naturally by different requirements than the wall tiles, the same tendency in the method of manufacture is shown in France and England, which is being developed in Germany. Beside the ordinary products consisting of floor tiles very high in iron, or of tiles burnt from plastic clay to a light-colored stoneware body as they are furnished more or less hard by a number of brick works, and the artificial paving brick of Pest and Schattau, in Moravia, and the English blue bricks, those tiles which are known in Germany by the collective name of Mettlach tiles, deserve special attention.

Products of this type are represented by several factories. The most prominent are the works at Maubeuge, affiliated with the Mettlach works, and the works of Sandt & Company, at Feignies, which represent the same type of product. Besides these, there are a few other French establishments like Boulenger and Simon & Company, who possess the same body colors and designs, but who seem to lack the density and hardness of the Mettlach tile. Mosaic floor tiles, which apparently are good in quality, are also produced by the Wienerberg Brick Works, and the Minton works of Stoke-on-Trent. We cannot say that the products of the last firm are as durable as the Boch tile, at least as far as appearance goes. It is a well-known fact that the manufacture of these tiles is a very difficult one, not on account of the putting together of the design, but mostly owing to the high burning temperature which approaches the porcelain fire, and which destroys many of the colors used, of which some designs contain as many as ten. The durability of the tiles increases with the burning temperature at which they must be burnt, in order to vitrify perfectly to a dense and porcelain-like body.

FINE CLAYWARES

Among the finer claywares standing for high artistic excellence and careful technical treatment beyond the requirements of the ordinary pottery, we again find that the French wares monopolize the interest of the visitor. Although it seems natural that the fine claywares, faience and porcelain, should be especially preferred by the designers of the exhibition for various purposes of decoration, and though it was to be expected that the French factories would make special efforts to show their power in this particular industry, still, the visitor is surprised by the excellence of the French products, for this exposition is given its own peculiar expression by the faience so that all other clay products must step into the background. Though art-ware plays a different rôle in France than with us, of which the stores of the inner boulevards and the magazines of the cross streets of the rue Paradis-Poissoniéres give ample testimony, still one is apt to receive an erroneous impression of the status of the industry if one were to judge it solely by the impression made at the exposition. It is only possible to obtain a correct picture of the industry if one examines the stock rooms of the factories themselves, together with the objects exhibited at the exposition, as well as by studying the methods of manufacture. The conclusion will be arrived at that the exhibits do not represent the average quality of the industrial ware, but that they represent extraordinary efforts, showing only what can be done but not what is being done. Not infrequently the confession is heard at the factories that the objects exhibited have been specially made for this purpose, and that they do not represent the commercial side of the business.

There are faience and porcelain factories represented that have made only a few attempts in the direction of artistic pottery, the results of which as far as they are technically successful are shown in the exposition, although the factories themselves are not willing to continue these attempts. The great bulk of the industry is represented by the ordinary commercial ware (white domestic pottery with printed or poorly painted decorations), of which little is seen at the exposition, and that in a pavilion together with stoneware and ordinary pottery. These common products are entirely overwhelmed by the art-ware, and one not acquainted with industrial conditions might imagine that the ordinary products played only an inferior economic rôle.

The production of ceramic art-ware has always been prominent in France, ever since the Italian majolica was introduced, and the industry was protected and supported by art-loving princes. This condition was helped by the presence of excellent raw materials, and hence it is not surprising that France has trained a great number of artists in the service of the ceramic industries who, in part, seem to be working independently within rather small circles. The number of men active in these branches is indeed astonishingly great, and it is due to this fact that the faience industry occupies its present position, in which it not only stands comparison with the English industry, but even surpasses the latter in many respects.

It is not my intention to say that the results of the French industry are always good and worth imitating, and I even venture to say that it is hardly probable that another country will follow France in the direction she has taken.

In spite of all the disadvantages, due to the physical properties of faience, it has the advantage over the most perfect material, porcelain, that it is easier to mold and is better adapted to the molding of artistic shapes, owing to the slight shrinkage in the fire, and again it permits the use of brilliant and strong colors, owing to its very fusible lead glaze, colors which can never be applied on porcelain. The method of decoration, most generally employed, is that of the Barbotine painting, whose extent is unknown in Germany and not understood; it probably was developed from the *pâte sur pâte* painting of the porcelain industry, and it furnishes the finest pieces of the faience industry. Barbotine means engobe or paste, and Barbotine painting stands for a method of decoration which is essentially plastic in character, bringing out the colors by means of paste. The technical execution, which the writer had occasion to study at the well-known faience factory at Gien, which produced the largest and finest pieces of this character, is as follows: The pieces, tiles, flat pottery, or great urn-like vessels, are made in the usual way in plaster molds; they are all smooth in outline so as to offer large areas for the extensive boldly executed decorations. As soon as they have become stiff the paste is applied. This is, in part, a white, partly a colored clay body, by means of which the painting to be applied is indicated by a more or less thick application, and in heavy, coarse strokes of the brush. The decoration consists usually of flower and animal pieces, preferably birds, which are in this manner painted plastically, so to speak. After the drying, the pieces are taken to the biscuit-kiln and burnt to the required hardness. The painting indicated by plastic means is now carried out with underglaze colors and covered in a second burn with a very fusible lead glaze. By this treatment the painting seems to step bodily out of the background, which likewise is covered with paste, and never shows a smooth surface. Of course, the paste does not permit of fine drawing, like the smooth surface of the porcelain or whiteware; the drawing is rather coarse and crude when examined closely, being similar in appearance to the rough strokes of oil painting, but possessing a much higher gloss. The pieces so decorated must be examined from some distance, and this treatment is especially suitable for large pieces, vases, jardinières, etc. However, it will also apply to the small objects, but loses in character, owing to the necessarily fine lines of the design which cannot be drawn successfully with so coarse a material as clay paste. The main representatives of this direction of art are E. Gille, of Paris, with a vase 2 meters high, decorated by a painted group of chickens and turkeys in life size, Artique freres, of Paris, Huvelin, of Paris, with well-executed portraits of Thiers and Gambetta, the faience works of Gien, with great landscape paintings on oblong and round plates, Boulenger and de Riviere, at Choisy-le-roi, Haviland and Company, of Limoges, Laurim, at St. Clément, O. Miles, at Sévres, Lefort and Jouve, in Paris, F. Laudry, in Paris, Eugene Schopin, in Montigny, and others. I have named only those who make larger exhibits of faience; individual attempts are being made by a great many exhibitors.

Although faience, painted with paste, offers fine artistic effects, yet the technical side is open to criticism. The body in many cases is fine whiteware, in most, however, an ordinary clay containing iron or lime. The paste itself is, of course, a pure or colored pipe clay, which remains soft at the temperature at which the ware is burnt. The very fusible glaze is usually crazed, and the union between the paste and the body is often very imperfect, so that the cracking and peeling is observed. The imperfections, however, are not given any consideration in France, but the stress is laid on the total effect of the painting. Water and atmospheric influences are natural enemies of this technique and yet it is being used for such objects which constantly come in contact with water, like flower vases and jardinières. This defect, however, is admitted quite effectively by Haviland & Co., who furnish lacquered tin vessels to be placed inside of their faience pottery.

Another technique represented at the Vienna Exposition, only by two or three firms, but which is now being introduced in the French faience industry, is the painting in relief applied, however, to smaller objects, cups, plates, bottle-like ornamental vessels, vases and pitchers. It consists of the application of a thick relief-like coating of tin and lead enamel in lively colors produced by metallic oxides. The motive of the design, which may cover the entire surface, or a part of it, consists of flowers and fine wreaths of leaves, intricate arabesques or geometrical figures of oriental or Moorish taste. The contours of the drawing are outlined on a high-grade faience body either in fine black lines, or they are applied, as is done at Gien, by means of printing; the colored enamel is applied on the white portions between the lines, it being rubbed in mucilage water; the coating is several millimeters thick, and is applied by means of a brush; the enamel is burnt in a muffle. The black painted or printed outlines prevent the flowing together of the separate drops of enamel, which, after the burning, project in high relief above the surface. The individual drops of enamel can now be further treated with colors dissolved in a glaze or muffle colors, wherever this is necessary, so that light and shade are produced. In cases where only part of the surface is covered with enamel and larger monochrome spaces remain, these are covered with a craquel enamel. In many instances this is the intention, but as often as this result is produced by the technical conditions, since tin enamels hardly ever adhere to a body free from lime without crazing, and hence, the craquel effect would appear whether desired or not. At Gien, where the ground often consists of craquel enamel of a beautiful pearl-gray color, it was observed that this is ground very coarsely, and in the unburnt condition had a sandy, glittering appearance. The number of exhibitors who decorate their faience in this manner is very large. I will mention only J. Veillard & Company, of Bordeaux, the faience works of Gien, Th. Deck, of Paris, Boulenger, at Choisy-le-roi, Barbuet & Company, at Creil, Henri Beziat, of Paris, Champion, at Vangirard, Paris. A faience works at Longwy exhibited some very beautiful things of this sort in great quantity, whose name, however, I cannot give at present.

Another method of decoration used quite extensively consists in the application of colored glazes, in which a change of light and shade is produced by high or low relief decorations on the body. These are in part small vessels, but in part also larger ornamental pottery, decorated only in a few colors in contrast to the similarly treated English garden majolica. The glazes are usually intensely green, blue-brown, yellow and red in color, being transparent and quite high in lead; they are applied in rather thick layers and run quite strongly so that the bottom of the ware shows thick accumulations of glaze. The running of the glaze produces very pleasant color effects if different colored glazes are applied above each other so that they mingle when fused, and give rise to various gradations of color. This simple technique often produces very fine pieces. One of the exhibitors, O. Milet, at Sévres, gives to the faience of this kind a mottled appearance by sprinkling an opaque glaze on the transparent glaze, thus producing small bands and blotches, which gradually disappear by being dissolved more or less. This is accomplished by spraying opaque tin enamels on a uniform ground of transparent glaze, or by inserting coarse grains of the enamel into the glaze.

The technique applied by Th. Deck and other establishments deserves special attention, on account of the wonderful color effects produced, which closely imitate the émail cloisonné. This term is applied to a kind of enamel work in which the lines are produced by the insertion of fine gold and silver threads and fusing enamel into the surfaces thus produced. It is the object of the threads to represent delicate designs, twigs, birds, etc. Several exhibitors show pieces on which the ground for flower decorations, executed in brilliant colors with a plastic effect, consists of a matt platinum surface.

This method is modified in the faience industry by making the outlines of the drawings with a paste which only softens in the fire, but does not run, the lines being drawn in high relief, and the body being composed of a mixture of glaze and clay. The colors are now inserted between the lines, and larger or smaller colored surfaces of sometimes quite thick layers of glaze can be produced without the danger of the interflowing of the colors. Larger areas outlined in this manner appear thus uniformly colored; smaller areas can be shaded by applying the glaze in a thicker layer near the line which causes the color to become deeper. This technique is especially suited for the decoration of larger surfaces in conventional ornaments or geometric designs; it permits the application of thick layers of glaze, which if not colored too strongly, will remain perfectly transparent. At the same time the painting is rendered very brilliant in color. One of the finest pieces exhibited by Deck in this style is a large plate decorated by a painting representing a pheasant, which is remarkable for the brilliant coloring.

Beside this, faience ware is frequently found, which is made in agreeable colors, from yellow or reddish clay covered with a thin colorless glaze; the latter is decorated with transparent or opaque enamel or muffle colors.

It is not surprising that side by side with the numerous modern methods of decoration of faience we find the older techniques; a large number of exhibitors show ware representing imitations of the old Palissy ware, large pieces with fishes, crabs, snakes, bugs, and other animals. We also find some Italian majolica; this style of ware is overwhelmed by the new methods in the French division. On the other hand, a large number of French factories produce the old French faience of Rouen, Moustier and Nevers as well as Delft ware, and apparently this ware is not intended for decorative purposes, but for practical use. All these faience products are manufactured from a marl clay, being covered with a white enamel, on which the decoration is applied in the green condition. The Rouen faience is decorated with a delicate ornamentation of leaves, and that of Moustier with flowers in red and yellow. The faience of Nevers is enameled in blue, over which there is applied a white enamel for the painting, or reversely blue enamel painting on a white ground. The Delft faience, in shape and decoration, imitates the Chinese porcelain. These variations of faience pottery are represented especially by the firm of Fourmaintraux Courquin, at Desvres (Pas de Calais), Gallé, at Nancy, Abel Girard, at Apray, De la Hubandiére & Company, at Quimper, Jules Aubray, at Toul, Laurin, at St. Clement, Bardaurotte, Tartot, at Blois, Montagnon, at Nevers; the latter shows a mammoth round basin, one meter in diameter. A peculiar use of faience is being made by Beau and Porquier, who manufacture musical instruments (violins, cellos, horns) which are daintily decorated with flower designs.

Among the exhibits of terra cotta we find very dainty and pretty things which excel by their modeling. These are usually statuettes representing humorous scenes from every-day life; for instance, a group by Ladreyt, of Paris, representing a rat chase in a Paris street, or the Paris street characters by J. C. Laroche. These figures, which are seen in many Paris show windows, are either made in matt colors or are modeled from different artificially colored clays, so that the flesh parts, hair and clothing possess their respective colors. Less worthy of imitation is the terra cotta, which is observed occasionally, that is retouched with enamels so that, for instance, in female busts the earrings and necklaces consist of such enamels. This sort of work reminds one too much of pictures of princes with decorations made out of gilt paper and pasted on the design.

Reproductions of the oldest Roman-Gallic pottery, decorated in relief and covered with an extremely thin glossy luster, are exhibited by E. Constans, at Millau.

The stove industry is but weakly represented in the French division; this is due to the fact that in France the stove is almost entirely replaced by grates.

H. Delaisse, of Paris, exhibits a stove which is said to be decorated by inlaying colored clays in the manner of the Oiron faience; several low stoves in Gothic style are shown by Victor Voigt and L. Debecker with silver gray, brown and green glazes; Jules Loebnitz, of Paris, exhibits white and colored stove tiles, which are perfect in every way, and the best work exhibited along this line.

Although the faience products, owing to their large quantity and the variety of decoration and use, take first place in the exhibits of the clay industry, yet the exhibits of the stiff-appearing porcelain in the French exhibits, which is so difficult to work, offers many interesting features. Especial interest is aroused by the exhibit of the National manufactory at Sévres. The number of pieces produced by this factory is very great, and they are exhibited in a most advantageous place, together with the gobelins of the French government mills. With the exception of a few very fine table sets the ware consists entirely of decorated pieces. The smaller part represents the older manner of decoration in noble Greek shapes with corresponding ornamentation, leaving on the main body of the piece space for the application of painting and muffle colors executed in an artistically perfect technique. The greater part of the Sévres porcelain, however, inclines to the direction which has been taken by the French faience industry. Pâte sur pâte painting is used most extensively and is applied not only for the delicate floating figures of the older ware, but also in the decoration with flowers, birds, and butterflies, giving a decided plastic impression. At the same time underglaze colors in brilliant shades are used as in the faience industry. This arouses the suspicion that the glazes used must be much softer than the usual hard porcelain glaze. Although, as a whole, the exhibit of Sévres is very imposing, on closer examination it is found that beside the perfect pieces some are shown which are technically imperfect and do not make a good impression on the expert. Warped pieces and blistered, dull, and flown glazes are noticed in a number of pieces.

A tendency is noticed in the French industry to decorate the porcelain no longer white, but to make a larger use of underglaze colors and colored glazes as it is being done in the faience industry. Of course, the technical difficulties are very great, and the number of colors used must necessarily be smaller than for faience; hence these efforts are only in the beginning. Some of the works show rather rich collections of colored porcelain. Prominent in this line is the work of Pillivuyt & Co., at Mehun and Nevers, A. Mache, Pepin & Lehalleur, at Vierzon, and Pouyat fréres, at Limoges; other Limosine factories exhibit a few attempts of this character. The colors are restricted to blue, green, and gray shades using cobalt, chromium, iron, manganese, and rose obtained by gold, but the tendency of these colors to change to gray gives to the ware a rather sombre appearance. The factories most largely represented are those of Limoges, which are strongest in white porcelain. Limoges possesses thirty-six odd porcelain potteries of which, however, quite a number are very small and work with only one or two kilns. The most important ones are L. Sazerat, Pouyat fréres, Haviland & Co., Gibus & Redon, Querin & Co. The porcelain manufacturers of this district possess most excellent raw materials, consisting of the kaolin and pegmatite from near St. Yrieux, which produce a porcelain of great beauty and extraordinary translucency even in ordinary ware, the color being a pale green. The Limoges works exhibit but a small amount of porcelain decorated with muffle colors, and on visiting the various factories it is found that they are not any better nor worse than the average German pottery. On the other hand, however, *pâte sur pâte* painting is being done on art ware; thus Gibus & Redon exhibit several pieces with three colors superimposed upon each other. The technique of the *pâte sur pâte* painting consists in the application of relief painting by means of a white or light colored porcelain paste upon a colored porcelain body, so that the darker ground appears through the varying thickness of this coating and produces an agreeable soft shading. The objects to be decorated are molded in the ordinary manner from a colored porcelain body to which is added cobalt oxide for blue, chromium oxide for green, gold purple for red, etc., or again the ordinary white porcelain body is covered with a colored engobe. For this purpose the colored body is poured into a plaster mold, allowed to remain in the latter for a few minutes and then poured off, thus causing a layer of colored body to remain on the plaster which is 1 to 2 mm. thick. The mold is now again filled with white slip, the casting being done in the ordinary manner. The decoration is applied after a soft burn by means of the brush, using a body paste, as a bas relief, which, after thorough drying, is completed by means of the modeling tool.

A very simple, and in many cases, a very useful method of decoration is one practiced of late at the Sévres works, as well as at several of the Limoges potteries, which seems to have been borrowed from the Chinese porcelain, but is being claimed by one of the Limoges potteries as its own invention; this is the emaillage ajour or "Aurora." It consists in perforating the walls of the ware by molding and cutting, forming delicate designs, or in boring round holes into the body according to a definite scheme before the biscuits burn, and filling these openings either with an ordinary white or a colored porcelain glaze. In the glost burn these openings, if they are sufficiently small, are closed by a semi-transparent glaze.

In regard to the other products of the porcelain industry, I will mention only the fact that a great number of flower works have exhibited the most delicate porcelain flowers and a series of paintings on richly decorated porcelain. Among the biscuit porcelain amply represented by statuettes and figures, we again find those which are decorated in colors such as the red terra cotta before mentioned, with a simultaneous application of different colored bodies. There is to be mentioned also the iridescent porcelain of Brianchon, of Paris, which was already exhibited at Vienna.

Besides the products of the French industry our interest is aroused by the English wares. Owing to the great export of English products and the purely practical aims of the Englishman it is not surprising to note that the business interests are represented more completely than is the case with the French exhibitors; for this rèason much more room is given to useful products in the English division than in the French. Even the pure art ware invariably suggests a practical use, owing to the application of more solid bodies and glazes, although at the expense of color effect. With the exception of a few modest attempts, the English exhibits show nothing of the suddenly developed growth of the faience industry, and it even seems that the English majolica is not as richly represented as it was at Vienna. The English industry exhibits a few technical novelties which are shown for the first time. The bulk of the exhibits naturally consists of white stoneware and bodies related to it, which, by printing and subsequent filling out, are decorated in various ways, or show decorations produced by means of metallic lusters or flowing colors; next to this kind of ware in importance rank the wall and mantel tiles in every conceivable technical and artistic treatment. A new technique of decoration for colored household pottery (pitchers, coffee and tea sets) which deserves general reproduction is that exhibited by W. & J. Bailey, at Alloa, J. Wedgewood & Son, at Etruria, Adams & Bromley, at Hanley, which seems to find special favor. It depends on the use of the sand-blast process which is already being used in Germany for the decoration of stove tiles and mantels. The pottery usually covered with a dark colored glaze, brown or blue, is etched by means of a stream of air or steam carrying the sand, the latter being blown against an elastic design, cut out, representing landscapes or figures which, owing to the thinning down of the glaze, show in contrast to the darker ground. This etching appears either as matt lines on the shining glaze, or it has again been made glossy by a second burning, which has softened the glaze.

Of the well-known English products the Doulton ware (stoneware made at Lambeth, a suburb of London) has for years found special favor. For a number of years this gray salt-glazed stoneware, which is remarkable for its great durability, and is being burnt in the open kiln, has been used most extensively for sewer and water-pipes, stop-cocks, condensers, bottles and other vessels used for chemical and domestic purposes. To-day a considerable and prominent industry has been developed from this material. At the Vienna Exposition, already, the work of

Doulton & Company aroused the interest of the public, although those exhibits were simply made to show what can be done, and were not considered from the commercial standpoint. This stoneware is represented by plain pottery of grayish or yellowish color, whose shades remind one of the old Rhennish and Flemish pottery, in which very delicate drawings are excised with a few lines, which are made prominent by being colored with brown or blue glaze. This modest beginning has of late years been widely developed, not only by Doulton, but also by other establishments like Howell, James & Co., and Jas. Stiff & Son, at Lambeth. The Doulton exhibit is one of the most interesting exhibits for the ceramist, because it shows a new kind of product which might be designated as stoneware majolica. Doulton, in his extensive exhibit, has not confined himself to the developing of the older technique, but he has made use of the plasticity of the clay by producing richly ornamented pottery and raising the effect of this decoration by the application of colored glazes. The ornaments are in part molded in plaster molds together with the entire piece and in part separately. They are then attached to the ware when still green. The smooth surfaces are decorated by excision of the designs in the old manner, or by colored glazes, whose contours are outlined by excised lines; in many cases he uses opaque enamels in place of a transparent glaze, or both. In the use of colors, which naturally are applied only after the first burning in the salt fire, some decided limitations are set on account of the dark-colored background, but yet the scale of colors is rich enough to produce very lively effects in connection with the plastic ornamentation.

Besides the Doulton exhibit, that of Minton, at Stoke, is especially prominent; but here it is not a single technique which arouses our interest, but the variety of the treatment shown by this manufacturer. Minton represents all classes of ceramic ware produced by the English industry.

The bulk of the English pottery, including artistic ware, consists of whiteware, while porcelain, which we consider the material most suited for domestic pottery, is found in the English exhibit only in objects of the highest value.

Not only in the Minton products, but also in the ware produced by other firms, like Copeland & Co., the Worcester Royal Works, Daniell & Son, and others, porcelain forms the basis of the most valuable pieces in the English exhibit. This porcelain is to be distinguished from the German porcelain: it is not a hard feldspar body, but a bone china covered with a lead glaze, which is the only kind produced in England, and which, on account of its soft glaze, is much better suited for colored decoration than our hard porcelain. Among the English porcelain there is a special kind—that of the Royal Porcelain works at Worcester—which looks very much like ivory. This establishment makes this ware the bulk of its exhibit and shows some valuable pieces.

Italy is represented at the exposition mainly by those works which have taken up the production of the old Italian majolica. Most of the pottery exhibited, however, consists only of weak reproductions of the old work, and but few potteries excel by superior workmanship. Among the latter there are to be mentioned Hannibal Fernani, of Faenza, who exhibits larger pieces in the Robbia style, Anghelo Minghetti & Figli, at Bologne, Jafet Torelli, who show Etrurian vases. Torqato Castellani, of Rome, Farina & Fils, at Faenza, and especially the well-known pottery of Ginori, at Doccia, exhibit painted faience.

Outside of the Italian majolica which is produced technically more perfect by the last-named firm, it has obtained a great reputation from its porcelain which is remarkable for the method of its decoration. The porcelains of Doccia are distinguished from the other products by the fact that all painting of smooth surfaces is avoided, and that all the decorations appear as haute or bas relief, which is made more prominent by colors.

Good work has been done by the few Swiss exhibitors. The majolicas of Eier and of Kuenzi, of Heinberg, are being bought up by collectors of colored faience like no other product. These excel, by their very lively colors. The designs are, however, very plain, showing the spirit of the peasant. They are domestic pottery with a whitish, porous body colored with dark, very brilliant, colors on which flowers and arabesques of colored glaze are applied in red, yellow, white, blue, and gray by means of the paint tube of the peasant potter. The contours of the painting are first outlined with a pencil. This ware, owing to the plainness and the simplicity of the means applied, its fine drawing, and its lively and harmonious colors, possesses a peculiar and attractive appearance, and it is readily understood why the market of the great city has been opened to the products of a quiet mountain village.

The Austrian industry, considering its importance, is represented very weakly. The great number of Bohemian porcelain works are represented only by the firm of Fischer and Mieg, at Carlsbad, whose exhibit made a good impression. Beside a large collection of richly decorated table porcelain, we find a great deal of artistic ware representing an effort which is unusual for private undertakings. Beside the ordinary method of porcelain decoration with muffle colors (gold, platinum and bronze), we find some underglaze decoration in blue represented by very beautiful pieces. Among these there is to be mentioned one of the largest pieces of the porcelain industry, an oval platter about 1.2 meters long and 0.5 meter wide. Beside this firm, some majolica is exhibited by the Wienerberg Building Company, together with some beautiful terra cotta and wall and floor tiles. In the Hungarian division we find, beside a rich exhibit of porcelain by the firm of Fischer Sons, at Herend, and reproductions of older porcelain by Fischer de Farkashazi, at Tata, a very pretty exhibit of faience and majolica. These are the products of Zsolny, Vilmos, at Pecset and Zsolny, Quillam, at Pecs, as well as of F. Fischer, at Pest. They are mostly smaller objects, small cups, pitchers, mugs and bottles made partly of a yellowish faience body, partly from a light-colored stoneware-like body on which are applied colored enamels and transparent glazes, often in relief-like painting, in a very pretty style. The stove industry is represented in the Hungarian division, especially by Ignace Fischer, at Pest, who shows a few of very pleasing stoves glazed in green and brown and decorated in the Gothic style.

There is very little to report about the Russian industry. The clay-working establishment "Arabia," at Helsingfors, exhibits ordinary printed whiteware which is very similar to the ordinary English ware, and also a number of larger pieces of majolica made in the English manner, and a few pieces of faience in the Palissy manner of decoration. The porcelain pottery of Cybulski, at Cmielow, shows only some cooking ware with a white and brown glaze of the type of the Bunzlau pottery. There are to be noted also a few efforts of the stove industry represented by L. Dietrich, at Warsaw, and by Gussareff, at Moscow, which are of inferior technical value. Somewhat better ware is exhibited by W. Andsten, at Helsingfors.

Sweden is represented most excellently by the two potteries, Roerstrand and Gustavsberg. The first of these factories excels by a number of richly decorated stoves molded from a fine whiteware body in the rococo style and glazed in the manner of majolica with very bright, rich colors. The prices of these pieces vary considerably and fluctuate between 1500 and 5000 francs. At the same time there are exhibited large majolica chandeliers decorated in the same style, and a large collection of painted and printed porcelain. Among the decorative porcelain, two vases glazed in black and dark blue with brilliant gloss excel especially; these are decorated in the exquisite designs of Greek vases with white enamel. The Gustavsberg pottery exhibits products similar to those of the first-named firm, but does not show any large pieces. They are content to exhibit a few very beautiful, majolica chandeliers and pitchers, faience (in cream color) domestic pottery, wash services, and printed tableware. Of their porcelain art products there are to be mentioned vases decorated with white enamel and statues of a cream color, made from a waxy, translucent, parian body, whose manufacture is apparently being cultivated on a large scale, to judge from the great number of objects exhibited.

The Danish division is characterized by the products with which we have been acquainted for a long time, originating from the factory of Ipsen, at Copenhagen. These are red terra cotta vases and basins which are modeled after the old Etrurian vases, and which also are decorated in the same style with black paintings; in part, they have a black background with red designs.

The manufacture seems to be carried on at Copenhagen on an extensive basis, for several other establishments exhibit ware similar to those of the oldest firm. These are Wendrich & Sonnes, and Peter Schou, both of Copenhagen. Besides these we find a comparatively rich exhibit of the former Royal Porcelain manufactory with old and new porcelain following, in shape and painting, the product of the Meissen pottery.

Of Dutch claywares we find exhibited, beside clay pipes, only ordinary white and printed faience by the Société ceramique Mastricht-Wyck, as well as an attempt by F. Thooft, Delft, who endeavors to revive the old, once famous, Delft faience. As a whole, these products, which formerly took the place of the expensive Chinese porcelain, are of a mediocre character. More skill and success is represented by the products of the Belgium establishment, Boch fréres, of the same class of faience, which includes a number of extraordinarily large pieces. Among these pieces there are to be mentioned, especially, basins 80 cm. in diameter and a vase 1.6 meters high decorated with a uniform enamel somewhat crazed and a rich blue painting executed on the unburnt glaze.

The same firm exhibits complete room furnishings, mantels, table-plates, sills, paintings, lamps, chandeliers, etc., in Delft faience. Of other Belgium products, we find paintings on tile and basins of faience and porcelain executed by a few painters like Tourteau, Gasparoli, and Gilbert, of Brussels, which, however, offer nothing of special interest.

The Dukedom of Luxembourg is represented by a single establishment, the branch of the firm of Villeroy & Boch, at Septfontaines; this is in some respects the only German establishment which takes part in the exposition, but under a foreign flag. Among the products of this famous, well-known firm, building terra cotta, floor tile, and fine whiteware, which excel by an extraordinary solid treatment, the chromolith products, deserve special mention because they have been attempted by no other exhibitors. These products are ornamental pottery from a fine, strongly colored whiteware body which appears to show some similarity to the bodies used in the production of the Mettlach floor tile. These colors are very durable; perfectly vitrified bodies are inlaid in each other, forming delicate ornaments and figured designs; a great number of different colors are used.

The smallest of the European states, Monaco, according to the quantity of the pieces exhibited, belongs to the larger exhibitors, for not only the space allowed the little country is filled by the various clay products, but the latter are also used frequently for decorative purposes. Only one kind of product deserves special mention, which, though offering no new shapes and decorations, excels by fresh colors and truth to nature; it is designated as majolica, but gives rise to the suspicion that it might belong to the class of siderolith ware, that is, clay painted with varnish colors. The motive and the decoration are always the same, baskets in all sizes and shapes formed from very fine clay bars which are covered by flowers and fruits. We cannot admire the colored decoration, but are compelled to praise the skill and care shown in the modeling.

The porcelain and faience exhibited by Spain and Portugal are hardly worth mentioning, and they occupy a very low position. Only one kind of Spanish clayware has found favor with many collectors. These are cooling jugs, formed by hand and decorated with a crude, but not unpleasant ornamentation, incised leaves and flower designs; small quartz splinters are pressed into the soft clay along the lines of the design.

In conclusion we could describe the clay products produced by countries outside of Europe, especially China and Japan, the home of the porcelain, both of which exhibit very extensively. The Chinese division, with its porcelain vases and grotesque painting, does not offer anything new, nothing which could not be seen in the stores and museums of any large city. The Japanese division, however, is interesting, not on account of the variety and taste of the decoration, but owing to the technical perfection. The porcelains, which are represented by small cups as thin as paper and painted basins, up to 1 meter in diameter, are decorated largely with blue underglaze painting in the manner which we know as peculiar to Japanese products, the designs being graceful and free from all perspective. At the same time gilding and lead enamel painting play an important rôle. Especially beautiful effects are produced by the use of different shades of gold, weak and strong, matt and shining. Besides the porcelain we observe the beautiful dark reddish brown whiteware and faience now being introduced in Europe. The faience exhibited is made almost entirely from a pale buff or flesh-colored clay decorated with thick transparent colors on a thin, bright glaze in the manner of all other Japanese products.

Examination of Two Floor Tile Bodies

ALBERT BLEININGER, B.SC., TRANSLATOR

For some years floor tiles have been sold in Berlin, which, though they do not show the extraordinary hardness of the famous Mettlach tiles, are quite durable and excel by their agreeable colors. These products come from some Rhenish and Lorraine establishments, show a strong yellow and again a deep black color, and are very exact in shape. The latter, especially, are of great beauty, and it was an interesting task to determine whether these are colored by metallic stains, or whether a process of smoking, discussed in these pages on several occasions, has been applied. For this purpose the bodies of two tiles, the one black the other yellow, both showing the same factory stamp, were subjected to chemical analysis, which gave the following results:

	Yellow tile. Per cent.	Black tile. Per cent.
Silica	51.84	52.89
Alumina	19.71	19.75
Ferric oxide	2.34	——
Ferrous oxide	——	1.97
Manganous oxide	trace	trace
Calcium oxide	23.35	22.88
Magnesium oxide	0.60	0.45
Carbon	——	0.38
Alkalies and loss	2.16	1.68
	100.00	100.00

These analyses show that no coloring substances have been added to the body since the composition in both cases was almost exactly the same, but that the color had been developed by the process of "smoking." It does not matter which of the different methods of smoking has been used, but from the very low content of iron in the body, the content of carbon in the black tile and the great uniformity of the black color, it may be assumed that the blackening was accomplished in saggars, the tiles having been covered with some powdered carbonaceous matter. In the body of both tiles we find an extraordinary high content of lime, so that in connection with the high content of alumina and the small amount of iron (assuming that the lime and the sand grains of the body which represent part of the silica found are absent), the assumption is justified that it is composed of a mixture of a plastic refractory clay with sand and a large amount of lime as flux. The addition of calcium carbonate in the shape of chalk, or similar material, not only adds a flux to the body, but also prevents warping, and makes possible the production of exact surfaces. Experiments have shown the remarkable fact that of mixtures of fire-clay with chalk burned in the same saggar at the same temperature, those show the smallest shrinkage which possess a content of 25 per cent, or thereabouts, of calcium carbonate, while the shrinkage increases with a larger or smaller content of the latter.

The Manufacture of Gas Retorts

ALBERT BLEININGER, B.SC., TRANSLATOR

Many difficulties are met in the manufacture of large pieces of clayware. The defects due to faulty mixing and pugging and to the drying, burning, and shrinkage are observed in a much greater degree than in smaller objects. Another factor of importance is that the body must be worked in a stiff condition, which is necessary in order that the freshly molded pieces shall not be crushed or deformed by their own weight. It is evident that this stiffness counteracts the continuity of the body. The largest pieces of clayware that are made are, without doubt, the retorts used in the production of illuminating gas from mineral or vegetable fuel, which often are made in one piece, 3.45 meters long, and which, in the green condition, weigh up to 3000 pounds.

The requirements to which these products are subject are first of all an eminent degree of refractory power and maximum resistance to mechanical abrasion, while in a state of red heat, and at the same time they must withstand sudden changes in temperature, that is, they must possess great toughness not shown ordinarily by claywares.

How these various requirements are fulfilled will be shown by the following method of manufacture which is practiced in a North German establishment.

Let us first consider the raw materials used and the manner of their preparation. The clay used is in part a slightly plastic, kaolin-like material from Halle, and in part a very plastic clay from Nassau, both being refractory; if we ask why a mixture of these two is necessary, and why one of them would not answer the purpose, we find the reason for this in the behavior of the two in the wet condition and at a high temperature. The first, at a very high heat, produces a very tough and resistant body without any further addition, but it does not possess the required degree of plasticity and bonding power for cementing the very coarse-grained grog body which alone can be used here, while the Nassau plastic clay is extremely suitable for this latter purpose, but if used alone would give too brittle a bond, and hence, the necessary properties could not be produced. In practical work a mixture of the two in the proportion of two to one has proved the most suitable.

In order to make the union of the clays, as well as their mixture with the grog, as complete as possible, they are, when perfectly air-dry, crushed and sieved and made up with hot water to a thin slip; this is done in soaking pits about 2 meters square and 0.5 meter deep, whose bottom consists of wooden planking.

After the clay has been completely softened to an even slip, which is stirred frequently, it is mixed with grog in an adjoining pit of equal size, the grog being spread out in alternating layers 2 to 3 cm. thick.

The grog used is quite coarse, owing to the fact that the retorts are to be as resisting as possible to sudden changes in temperature. The grog is sized by rejecting all grains which do not go through a sieve with meshes 1 cm. square, as well as those which pass through a sieve with a 3 mm. mesh, so that in this case the grog is not only a leaning material, but must be considered as a constituent of the body proper, the larger and smaller sharp-cornered and irregular fragments of grog being cemented together by the clay to form a continuous body.

The material used for the grog consists of hard-burnt refractory clay from old fire-brick, broken retorts, saggars used in the manufacture of porcelain, etc. Care must, however, be taken to remove any adhering slag, glaze or other impurities which might act as fluxes. The shape and the surface of the grains of grog are of the greatest importance; they must be as sharp-cornered and splintery as possible in order to make possible perfect cementing of the bonding clay. For this reason any refractory material which does not possess these properties (for instance, quartz sand with rounded and smooth grains) must be rejected.

The crushing of the grog is done by means of rolls, the distance between the rolls being about 1 cm.; the coarse grog is separated by means of a screen whose meshes are 1 cm. wide, while the dust is removed by means of a sieve with 3 mm. mesh, so that the grain of the grog used is between the size of a pea and that of a pin head.

The mixtures which are used are as follows:

4 parts by volume of finely ground Halle clay.
2 parts by volume of finely ground Nassau clay.
8 parts by volume of grog in grains the size of a pea.
2 parts by volume of grog in size of a pin head.

After these materials are put into the soaking pit in as thin and uniform layers as possible, and after the clay is added in the condition of a slip, part of the water of the clay is taken up by the grog and the entire mass is conveyed to the pug mill, where it is made up to a uniform body.

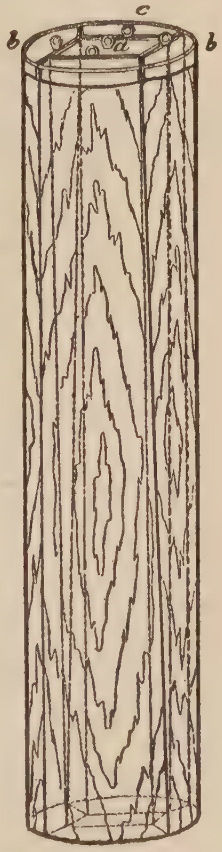
As has been said before, the body must be worked as stiff as possible, owing to the great weight of the objects, in fact, it must be so stiff that a pug mill could not work it in this condition; for this reason it is made homogeneous in the pug mill in the soft condition, and then as much water is removed from it as is necessary to bring it to the required condition.

The excess of water is removed by spreading the body in a layer 5 to 8 cm. thick on a paved floor, which is being heated by a flue, through which the waste gases from a boiler are drawn. The body is dried in this manner until it is so stiff that it can be kneaded with the hand only difficultly, and can be united to form a larger ball only by the application of considerable pressure, or by strong blows. After this has been done the balls of clay are united into a lump 1.5 to 2 meters square and as high, any portions which are too dry being moistened with water; the body takes up water very readily in spite of its content of plastic clay, owing to the fact that it contains such a high percentage of grog. The clay is worked into a uniform mass by means of heavy wooden mallets, and is kept covered with a wet cloth for twenty-four to forty-eight hours in order that any inequalities in regard to moistness may be equalized. The body is taken from these large lumps, by means of a knife, in shavings 1 to 2 cm. thick, these being crumbled by the hand; the body is a loose mass, crumbly and coarse-grained and so slightly plastic that it can be united only by the application of considerable force.

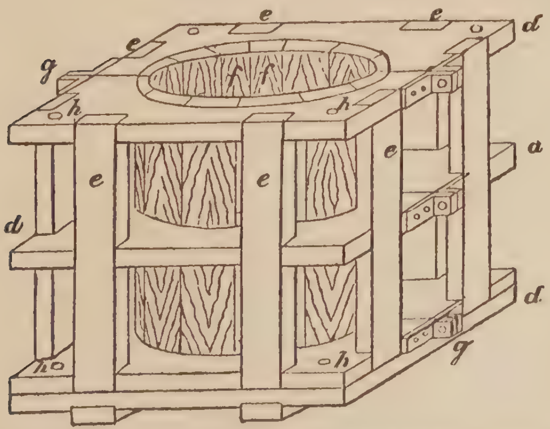
This slight degree of plasticity is necessary in order to reduce the shrinkage of the body to a minimum; of course, what the body lacks in working quality must be supplied by a greater application of force in the working; on the other hand, it can, by being worked vigorously, be made to form such a dense mass, as could never be obtained from a soft body, which gives way to every blow.

The molds into which the body is rammed must, of course, be made in pieces, because otherwise the retorts could not be removed. They are made of wood, and after being cleaned thoroughly they are oiled before being used in order that the grog body shall not adhere to it.

The retorts used in the manufacture of gas are pipes 7 to 11 feet long, closed at one end, of elliptical section or ⌓-shaped, but rarely of round cross-section. The inside width of the elliptical retorts is 34 to 36 cm. along the short, and 52 to 58 cm. along the large diameter. The ⌓-shaped retorts are 52 cm. wide at the base and 39 to 47 cm. high. The walls of the retorts are usually 6–7.25 cm. thick, being somewhat thicker at the open end. If the retorts are not closed the thickness is increased to 13 cm. so that bolts can be inserted, which hold in place the cast-iron fittings, that close the retorts and carry off the gases.



The mold consists of two parts, the core and the exterior mantle, both, of course, corresponding to the dimensions and shape of the retort. I shall describe only the mold which is used in making the elliptical retorts.



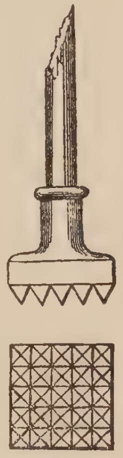
The core consists of five parts, a center piece, *a*, which converges from top to bottom on all four surfaces, two side pieces, *b b*, at the strongest curvature, which must fill out towards the bottom, and the side pieces *c c*, which complete the flatter curvatures; these are thinner towards the top. These five parts are so shaped that they form, when put together and fastened by bands, a solid block whose dimensions correspond to the interior space of the retort. Each of the parts is bound on top with iron and provided with a hook so that after the tamping is finished they can be loosened by means of a screw and hoisted out by means of block and tackle.

The outer parts of the mold consist of a wooden bottom reinforced by cross-pieces, which is about 1 meter square, and six to eight mantel-pieces according to the length, two of which are always connected so that they form a pipe, so to speak, whose lumen corresponds to the exterior shape of the retort.

The mantel-pieces consist of three pieces of planking, *d*, with an elliptical opening, which are kept separated by means of four pieces, *e e*, at equal distances. In the curved part the boards *f f*, which form the interior of the mold, are put in position like barrel staves. Every pair of these halves can be clamped together by means of the angle irons *g g* fastened to the planking. By means of holes, *h h*, bored in the corners, the halves can be connected with the bottom or a second similar section of the mold so that the exterior part of the mold must be extended by connecting with new sections, as the tamping of the clay progresses. For the upper, thicker part of the retort at the open end, a specially shaped piece is bolted on which permits of molding a thicker wall.

The tamping in of the clay is done as follows:

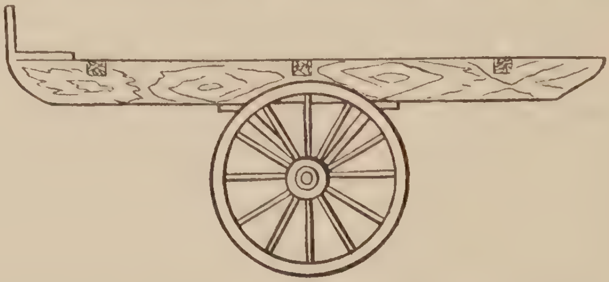
First the bottom is placed in the exact horizontal position by means of wedges and the halves of the first mold section are connected with each other and the bottom. In order to insure perfect closing of the mold joints during the tamping, iron hoops are fastened around the shell by means of turn-bolts. The bottom of the retort is now made by spreading out the clay body, which is crumbly and is being cut from the pile in shavings, in even layers about an inch thick and then tamping it together. The rammer used for this purpose has a cast-iron head weighing about 25 kg. (see accompanying figure). On its square bottom surface it is corrugated by grooves about 2 cm. deep, at right angles to each other, so that twenty-five pyramidal teeth are formed. In working with this tool the body is being continually kneaded, all the pores are opened, and the grog body is firmly united and knit together. As soon as a layer about 3 inches deep has been tamped it is smoothed by means of an iron tamper with a smooth head, and the building up of the wall is now begun. For this purpose the core, whose parts are held together by iron hoops, is placed in the exact vertical position, being centered accurately by means of wedges, so that it is equally distant all around the circumference, as well as fixed firmly. The space between the core and the mold shell is now gradually filled with the crumbly clay in layers about 1–1.5 inches deep and the clay firmly tamped by means of a tamper weighing about 10 kg., whose cast-iron head is 3 inches long and 2 inches wide, and has six teeth about 2 cm. long.



As soon as the space between the first section of the shell and core is filled almost to the top, the clay surrounding the core will hold it firmly in position and the centering wedges, as well as the hoops around the core, can be removed and the two halves of another section can be bolted on. This is kept up till the retort has been made high enough.

As soon as the retort has been tamped to the required height, a special piece being bolted on at the top for increasing the thickness of the wall to 5 inches, the holes necessary for the cementing in of the bolts which hold the cast-iron mouth-piece in position, are made in the heavier section. The core is then removed at once by lifting out first the wedge-like center-piece *a*, followed by the converging side-pieces *b b*, and finally by the pieces *c c*, using block and tackle.

Tamping does not produce sufficient density of the body, owing to the great resistance offered by the material, and it must be compressed still more by working the inner and outer walls of the retort. For this purpose the retort is placed in a horizontal position, without, however, removing the exterior parts of the mold. A two-wheeled truck serves for this purpose, as shown in the accompanying illustration, this truck being also



used in conveying the piece to the place where it is dried. Two long pieces of wood are connected by cross-pieces in intervals of 2 feet, and they are supported in the middle by two wheels. At the one end of the long pieces, an angle iron is attached which is placed in position beneath the bottom of the mold, the truck being vertical, so that the long wooden pieces touch the exterior of the retort mold. After both are fastened by means of straps they are let down together upon the wheel by means of a pulley suspended to the roof timber. A workman now crawls into the inside of the retort resting horizontally on the truck, and, lying on a piece of board, he commences to work the interior walls by means of a board till all inequalities and pores have disappeared. He also gives the interior surface a coating of mortar, consisting of 4 parts of grog dust and 1 part of clay, this being applied first by means of a felt pad and then rubbed firmly with a smooth iron plate in order to close the pores and to provide a suitable ground for the glaze to be applied later.

After the finishing and smoothing of the interior the exterior mold can be removed and then the outer surface may be smoothed. The tamping and finishing of the interior requires about eight hours of work. The retort is now taken to the drying-space, since after removing the outer part of the mold it cannot be handled till it has become air-dry. For this reason it is again placed upon the bottom board, the outer parts of the mold taken apart piece by piece, and the tube placed in the vertical position by means of wedges, which are placed beneath the bottom plate, and the outer walls are smoothed and coated with mortar exactly like the interior wall.

The drying of such a large piece must, of course, be carried on with great care, and in the summer it is accomplished either without artificial heat in a place protected from the wind and sun or in the winter in a drying chamber heated to 30°–40° C., or by means of suspended coal baskets.

The latter method of drying is very cumbersome, requires much care, and should not be used except in case of necessity as it is always a dangerous practice.

A cylindrical basket, about 6 inches wide and 6 inches deep with perforated walls, is suspended by means of a chain exactly in the middle of the interior of the retort and filled with burning charcoal. In order that the heat evolved from the coal basket may be distributed uniformly over the entire mass of the retort, it is drawn up and down at short intervals, say every five minutes. After complete drying, the interior of the retort is glazed in order to make it impervious to gases. The retort is again turned over, which is done by means of the truck described above, the latter being provided with cushions to prevent any injury to the retort. The glaze consists of finely ground feldspar and gypsum and it is made up into a thin slip with the aid of glue and water, and is applied by means of a soft brush. This coating of glaze is also dried and, finally, the retort is wheeled to the kiln where it passes through the last process,—heating to an intense white heat.

The burning of the retorts is done in kilns which are similar to the porcelain and whiteware kilns, with two stories. The kilns are circular, and along the walls five grate furnaces are distributed on a level with the floor and a similar furnace is arranged in a pit below the door of the kiln which, during the filling and drawing of the kiln, is covered with planks. By means of a flue the flame evolved here is carried to the center of the circular kiln bottom. The lower kiln space is arched over at the height of 10 feet with a perforated arch, through which the gases are conducted into the second story. In the latter, only small pieces are burnt and the heat of the lower space kiln is thus utilized. The arch of the upper kiln space narrows to a stack, which on top is provided with a damper. The retorts are, of course, only burnt in the lower kiln space, and in a kiln 4 meters in diameter 24 to 25 retorts of the ordinary dimensions can be burnt.

The cylindrical kilns are braced and tied with iron bands, especially at the height of the skew back, which is supported by a projection from the wall. The bands are wedged with wooden pieces so as to offer an elastic resistance to the expansion of the kiln.

After the glaze has been applied to the interior of the retorts and dried they are wheeled to the kiln by means of the trucks described above and are set on the kiln floor, which is covered with finely ground, loose grog. By being moved carefully on this sand the retorts are pushed together as closely as possible and placed in an exactly plumbed position by means of embedding in the grog. If the retorts are longer than the height of the kiln, the sand is dug out in places where these long pieces are to be put and the retorts are then let into these recesses. The spaces between the retorts are filled with smaller pieces, usually ordinary fire and shape brick. In front of the openings in the wall through which the flame enters the kiln space from the grate, fire-clay tiles are loosely placed in position in order that the retorts may be protected from direct contact with the flame. After walling up the kiln door a small fire is at first maintained by means of coal, which is gradually increased until an intense white heat has been reached. This is continued until the glaze appears to flow smoothly on the trial pieces, which are placed beneath the peep-hole in the arch. The intense firing is kept up from seventy to eighty hours, the stack is then closed, and the fire-doors as well as the ash-pit holes tightly walled up so as to cool the ware as slowly as possible. Slow cooling is especially necessary and it is of great importance that the retorts be kept at a high temperature for a long while, so that they will not shrink any more when in use. The burning, including the filling and drawing, requires ten days.

Report of the Berlin Industrial Exhibition of 1879

STANLEY G. BURT, TRANSLATOR

On the first day of May the Berlin Industrial Exhibition was opened. It came like a bright life-giving sunbeam in the dull gloom of our business depression. Since Reuleaux charged us with being "cheap and poor," which impression, under the influence of an international depression, has sunk just so much the deeper, we have accustomed ourselves to hold our industrial ability too low. The protective tariff agitation, with the efforts in its behalf to paint our condition worse and worse, has instilled into us still further the feeling of business inability and robbed us of every hope for our industrial future. At this point comes the Berlin industry like a self-confident man not gaudily arrayed but plain and simple as the Germans prefer it, and to our astonished view unfolds a rich fulness of originality, energy, and intelligence. The observer is enthused, as if suddenly the sun breaking through the dark fog were again sending us our happy genius lost in the late years. The exhibition of this one industrial city, Berlin, awakes in us the feeling that we have been wrong to hold ourselves so low in the world's industrial strife and that we are approaching a hopeful future if we will only continue to work with earnestness and zeal in developing our industry. To have developed this hope alone is to be considered a great achievement of the Berlin Exhibition. This alone makes us deeply indebted to the men who brought it about and with energy and work, and without government assistance, raised it to such a complete representation of the Berlin industries.

We cannot go into details here, but must satisfy ourselves with wishing the undertaking all success. To our readers who can spare the time to visit the capital during the summer, we can promise an unusual stimulation and no small amount of enjoyment.

Now that the exhibits outside of the exhibition buildings and in the courts which have been so long delayed through bad weather have been finished we will no longer defer making a tour of the grounds with our readers. We do this more eagerly and with greater pleasure since here we will find a cheerful, hopeful picture in spite of the bad business situation which is everywhere working so distressfully upon our commerce. It is a proof that in spite of the many failures of exhibitions in recent years the German, and especially the Berlin, industries are in no way disheartened ; on the contrary they have profited by the faults of others and have exerted themselves to benefit by their deficiencies. They show no mere servile imitation of foreign products but are able to develop original ideas which are lacking neither in taste nor in technical or artistic ability, in fact certain branches might even take the leadership in the world's market. The exhibition offers in the style of a world's fair, on a small scale, a very satisfactory picture of the Berlin industrial activity. It is of a modest but worthy appearance, brought about through the efforts of a number of patriotic men, without government assistance. This has a stimulating effect upon every visitor and will give him more instruction than he could get from a world's fair, so overpowering and bewildering through its chaotic size.

Berlin, without coal or iron ore or other mineral wealth in its immediate neighborhood, with insufficient waterways, has still been able to develop into an important manufacturing city. Its manufacturing interests are not grounded upon the massive production of raw material but upon making this raw material into objects of use and luxury. Therefore, it is the little factories which are especially represented in Berlin. In these, careful, technical, and artistic treatment flourishes better than in the great factories for production on a large scale. While certain branches depend upon the manufacture of great quantities, and on this account have their center outside of Berlin, still these cannot altogether withdraw themselves from an artistic influence, and, in a measure, are compelled to throw off the character of factories. Others can only exist with the constant encouragement which the life of a great city alone can offer. The first statement is especially true of building materials, the latter of the artistic products of the clay industries. The lack of the necessary raw material, that is, of pure clay, in the neighborhood of Berlin has, of course, in no manner aided in the development of the clay industries. However, certain branches, thanks to the constant market of a great city, have reached a high technical and artistic development; of these, the manufacture of building material stands at the head, then come faience and majolica stoves, the manufacture of hard porcelain and china and the closely allied manufacture of fire-clay products, and finally that of sewer-pipe. Those factories which are located within Berlin or its immediate neighborhood use, without exception, raw materials brought from a distance. It is only in the case of terra cotta and drain tiles that certain Berlin firms have factories at the source of the raw material.

In the following paragraphs we will mention only the various industries as we come to the objects representing them. The machines which they use we shall discuss later.

FACE-BRICK AND TERRA COTTA

According to the program of the exhibition committee only exhibits made by Berlin firms were accepted. Therefore it is not surprising that the number of factories here represented which have decorated the monumental buildings of Berlin with face-brick is small. The immediate neighborhood of Berlin does not possess the necessary raw material, and transportation of the same, as can easily be understood, is out of the question. Still among the exhibitors, a number of the best factories are represented, which furnish the material for most of the buildings that are built of face-bricks.

Of these the catalogue gives the following names: the Greppin Works at Bitterfeld, Splau Clay Works at Wittenberg, Siegersdorf Works, Lindner Brick Works, at Birkenwerder, A. Muller's Brick Works, at Hennigsdorf, Noelte and Habildt, at Berlin, and the Hermsdorf Cement and Clay Works. Unfortunately, from a cause unknown to us, the March establishment is not represented. The three first-named firms are widely known, and produce a building material which, through its ability to withstand the weather and its pleasing yellow and brown color shades, is especially prized by the Berlin architects. Therefore, quite naturally, these materials find a prominent place in the buildings of the exposition. There are two buildings in the exposition well worth seeing, not only on account of the building material itself, but also from its artistic use. These are the wine room of Knoop & Son and the "Weissbier" room of the Berlin restaurant proprietors' club. Both were designed by the architect, Otzen, and carried out in the simplest manner known to brick architecture. These two buildings are between the columns supporting the elevated road which passes through the grounds. The first in gothic style, with high, pointed windows of brightly colored glass, has a large fireplace and dome-like ceiling supported by slender columns. The material necessary for these, both in shape and arch brick, was furnished by the Greppin Works four weeks after ordered. The "Weissbier" room is decorated with wall columns and niches and has a flat wooden ceiling. The walls are pleasingly decorated with dark matt glazed ornaments on a back ground of buff bricks. The material for this was taken directly from the stock of the Splau Clay Works. Finally the Siegersdorf Works furnished the material for the inner court of the Berlin City pavilion. The panels of this are of dark red bricks with trimmings of yellow-gray brick; unfortunately we cannot judge the value, as face-brick, of the first since they are covered with paint. In addition to these buildings all of the face-brick works have special exhibits which give a picture of the variety of their product and the character of the raw material used.

The Greppin Works exhibit a garden pavilion which is supported by high columns designed by the architects, Knoblauch and Wex, and further adorned by the sculptor, Thomas, with a seated figure upon a four-cornered pedestal. The richly ornamented parts of the building are a proof that this factory is expert not only in forming but also in coloring the material with which so many residences have been adorned. The exhibit of the Splau Clay Works and that of the Siegersdorf Works are in the court of the Berlin pavilion.

The first forms an ornamented wall finished by a balustrade. In addition to these are samples of ornamental brick decorated with simple geometrical figures either in relief, flat or recessed. The plain designs in dark colors with matt glazes in black, brown or blue, done in strong lines form a very pleasing impression, as for example in the "Weissbier" room. The exhibit of the Siegersdorf Works forms a platform surrounded by a balustrade and reached by a flight of stairs. The rear wall is finished with face-brick and the whole decorated with garden furniture of clay stands, medallions and vases. The color is yellow, brown or red, always having a pleasing grayish shade, and furnishes proof that this factory has a greater field in coloring by means of its natural raw material than have the other two competing firms previously mentioned. Another building material much prized in Berlin is that made from the calcareous clay. This through its pleasing yellow sulphur color is very highly prized, and specimens are shown by the Lindner Brick Works at Birkenwerder, Mueller at Hennigsdorf, and also by Noelte and Habild in Eberswalde. A rich choice of very carefully worked and evenly colored face- and profile-brick is shown by the Lindner Works next to the exhibit of the Siegersdorf Works. The boiler house built by A. Borsig shows the use of the Hennigsdorf bricks. The exhibit of face-brick from Noelte and Habild, judging from their red color, are not very hard-burned. They are to be found with the claywares inside the buildings.

The Hermsdorf Cement and Clay Works exhibit face-bricks, terra cotta of pale red color, garden and fountain figures throughout the grounds.

The Stove Industry

The manufacture of stoves has for a long time had a home in Berlin and has developed here into an important and characteristic industry, especially favored through having within easy reach the Velten clay bed, but three miles from Berlin. This clay is especially adapted to the manufacture of common faience and is shipped great distances, to St. Petersburg, Stockholm, Dresden and Vienna. Until recently the main object of the Berlin factories was to attain the highest technical excellency in their product. A perfect white and well covering enamel, absolute evenness of the tile, brilliancy and complete freedom from defects in the glaze, were considered the greatest triumph of the tile maker. The plastic decoration of the stoves still left a good deal to be desired. They were taken, however, by the architects for what they were worth and used, wherever possible, in a decorative way for living rooms. It was only within the last ten years that a marked influence originating from the architects to further develop this industry has been felt. First the plastic parts of the stove, the cornices, friezes, and medallions, were left more and more unglazed since the enamel often covered the delicate and artistic modeling so that nothing could be seen. In place of this a thin coat of oil color was used, which harmonized with its surroundings—the carpets and the furniture. Such a stove, supplying moderate demands in a living room, is the one most commonly in use not only in Berlin but in all Northern Germany, and will probably remain the principal heating arrangement, because of the relative cheapness of its construction and the satisfactory firing arrangement.

On the other hand, the effort is more and more felt to make the stove an adornment to the room, not only in its form but also in its color, harmonizing with the room, just as it did in the middle ages and in the beginning of modern times in France, Suabia, and Switzerland. This effort is worthy of development, and will eventually make the stove manufacture a genuine art industry, as it formerly was. This aim of the leading Berlin stove-makers, aided and encouraged by Berlin architects and skilled artists, has made it possible to gain for this industrial branch a most prominent position in the exhibition, and has enabled it to give a characteristic and interesting stamp not only to the clay industry as a whole but also to the furniture exhibits.

The form in which the stove is generally met in the exhibition is not the stiff, cold, white, homely, purely practical warmth-saver of the citizen's home but, on the contrary, is of a pleasing form, which enables it, during the time in which it is not fulfilling its practical object, to give us pleasure in viewing it. The staring, blameless white, shining surfaces have gone into the background and in their place we have rich modeling tiles with a wealth of colored transparent glazes or covered with painting.

In the majority of cases the stove appears as a fireplace or a grate-stove, that is, a combination of the unpleasant fireplace with the practical warmth-giving stove. Therefore, the white stove with glazed or painted ornaments seems to be driven into the background and only a few exhibitors show them as though to prove that they were still alive and had a right to exist alongside of their proud companions.

In the front rank of those striving to advance this industry in an artistic way is the Stove Manufacturing Co., formerly Gustav Dankberg, which, aided by the architects, Hugo Licht and Ihne and Stegemüller, and the sculptor, Otto Lessing, has produced a number of art stoves. Of these as specially noteworthy, we will only mention the Florentine grate-stove exhibited under the arch of the elevated road and the large one in the reading room of the Café Bauer. These are both carried out in the renaissance style decorated with rich plastic ornaments and covered with a transparent olive-green glaze which throws light and shade on the modeling from its thicker or thinner layers. Some of the modeled parts are, in addition, also colored with a glaze which harmonizes well with the ground tone. This work is not only praiseworthy from its design and color effect but also on account of the technical skill shown, since the tiles used in it are of extraordinary size.

Equally worthy is the work of the stove factory of O. Titel consisting of colored and white stoves; the same firm has produced the clay work of the architects, Kayser and Von Grossheim, consisting of colored faience tiles for fireplaces, and also a splendid picture painted by W. Timm, on a single large clay tile which serves as a medallion in the sandstone trimming of the marble fireplace. The stoves of this exhibitor consist partly of white tiles with painted ornaments, and partly of white tiles with decoration produced by means of stencils, of a blue color, while others are covered with transparent glazes mainly in green or light brown colors. Of the latter, one stove done in the Japanese style, designed by Kayser and Von Grossheim, deserves special mention. Its broad panels consist of white faience tiles decorated by the painter, W. Timm, in the Japanese style with scattered branches, birds and butterflies, done in true majolica style. The borders of these tiles are covered with light brown glazes, further ornamented with a simple twisting, incised line decoration. On the front, the following verse from "The Bell," "Wohlthätig ist des Feuers Macht, Wenn sie der Mensch bezähmt, bewacht, Doch furchtbar wird die Himmelskraft, Wenn sie der Fessel sich entrafft" is used as a very pleasing decoration. The letters are painted in a rhombic field in an entwined Gothic style, which, in its whole effect, gives the impression of Japanese letters and harmonizes with the whole character of the stove.

Unfortunately these big tiles, painted with great bravour, show slight defects due to the firing, which should remind the potter of the technical difficulties connected with this material and keep him from experimenting, which might endanger the work of the artist. We think that this excellent painting would have the same effect if done on many small tiles that it has upon a single large one. The risk of exposing the entire work of the artist by making so large a piece, where this is not absolutely necessary since the danger to the piece in firing increases with its size, especially with such a brittle material as the Velten clay, is too great in comparison to the honor to be gained from overcoming the technical difficulties.

A worthy neighbor to the booth of O. Titel is that of C. H. Herm. Schmidt. This firm has the cooperation of the architect, E. Sputh, for its designs and that of the sculptor, Doebbeke, for its modeling. The exhibit shows, in addition to a very fine kitchen hearth, a great number of the common Berlin stoves with painted ornaments and also many colored stoves and a large fireplace. This fireplace consists of ornamented tile covered with a transparent glaze of green, olive-brown or reddish brown color. In addition to these, separate parts of the stove are shown with colored glazes, also some very successful experiments in majolica in the Lucca della Robbia style. The decoration on one of the white stoves consisting of engraved work, obtained by means of a sand-blast (which, by the way, might form a very useful means for decorating pottery), shows a very pleasing effect by changing the brilliancy to a matt, and a delicate shading in color on the surface. In all pieces shown, there is the same mastery of the technical aids of this industry that all other exhibitors have shown. The experiments of C. A. Schuppmann in the decoration of his stoves are not quite so successful. He exhibits a stove of the old Berlin style, decorated with figures in high relief, whose delicate modeling is completely covered by the thick enamel and in which this modeling is sought to be brought out again by painting with porcelain colors. Although this style of decoration is by no means new in the manufacture of stoves and is more or less obvious in glazed work, and in many cases results in a very good effect, still it must be held within certain bounds. For example, it serves very well in cases where leaf or arabesque work is done in bas relief, whose low modeling almost completely disappears under the opaque glaze. In such cases the contours may be brought into relief by delicate, colored lines more suggestive than realized. The large figures on the coping of the stove and in the medallions are more stiff and less pleasing, with the hair, beard, and clothing painted in detail, as they are, than they would have been without this decoration. The delicacy of the modeling is almost completely lost under the colored opaque, and from its nature heavy, enamel. For this reason, this style of decoration should not be used, as it is not appropriate to the technical means employed. Had it been done with a better choice of transparent glazes it would have had a much more agreeable effect.

The exhibit of A. Drews shows in the same manner the difficulties which this enamel causes as soon as delicately modeled parts are to be covered. A large painted stove of the majolica style and of an intense yellow color with blue decoration is especially noticeable in this respect. The round raised disks on certain tiles are excellently painted on the unburnt glaze and would have been very effective with a different choice of colors and probably with other surroundings. However, as it is, the outlines concealed by the glaze show no relief and are coarse and unpleasing. Another stove of the same style shown by the same firm is much more satisfactory, showing a transparent green glaze without painted decoration. This is exhibited in the booth of Adolph Friedlander (Furniture) but is, however, not perfect in all parts of the glaze. Two other stoves by Drews, with a yellowish gray glaze of very pleasing color, which is not perfectly opaque, allows the relief decoration and the low relief designs to show through. This is a style which shows much less the faults of the tin enamel, and seems likely to prove more satisfactory than the painted ornaments which, judged from the standpoint of durability and cleanliness, leave a great deal to be desired in spite of their other advantages.

A stove exhibited by Romberg and Mehlmann has a pleasing appearance but is worthy of mention not so much from the potter's standpoint as from its special heating and ventilating arrangement. We will not go into details concerning the interior construction of this stove, since it has been discussed for some time in the technical journals.

Finally the column stoves of the porcelain and fire-clay factory of Opdenhoff Bros. consist partly of glazed fire-clay tiles and partly of fire-clay with a facing of hard porcelain, the latter, in very fine designs and of a very pleasing appearance, being decorated with gilding and fastened together by bronze rings.

MAJOLICA WORK

Although the faience factories, which have been for a long time so fully developed in Berlin, would seem to furnish favorable opportunities for the development of an artistic majolica industry, allied as it is to them, still experiments in this direction are only of recent date. The exhibition, however, proves that at the present moment these experiments are now being undertaken in various directions and from various standpoints, and are in a satisfactory state of development. The first attempt to establish a majolica factory in Berlin was made a few years ago by Geh. Kommerzienrath Louis Ravené, who was aided by a few prominent architects and who died a few weeks ago. He started a small factory for artistic majolica work aided by Italian material and workers. The attempt was, however, given up apparently because it was impossible to overcome the technical difficulties. This effort was not altogether in vain, since it aroused an active interest for this art industry among architects, painters and amateurs. The Industrial Museum also exerted a strong influence on this work, as the pieces exhibited plainly show. When we speak here of majolica work we mean not only that which should really be called majolica, in which the painting is done upon the unburnt glaze on common pottery (opaque tin-lead enamel, on a coarse, colored body containing lime), but also that which is pretty generally, though wrongly, called majolica, in which the painting is done under the glaze upon a white body (fine pottery and bone china), and also that in which the painting is done with colored glazes.

A. Drews, O. Titel, C. H. Herm. Schmidt and the Royal Porcelain Factory, exhibit genuine majolica, and the latter also majolica on bone china. F. S. West, Ww. & Co. show majolica on whiteware, while certain amateurs show a few pieces of the same in the furniture exhibit booths; finally A. Schuppmann shows work in the old Nuremburg style.

The work of A. Drews, which is mainly done by the artist Miss Drews, who was educated at the Industrial Museum, consists partly of stoves and partly of plaques. These serve as wall or fireplace decorations. One yellow stove that is especially noticeable, which, owing to its color, harmonizes little with its surroundings, has upon its relief parts a very firm fine painting. The color decoration of the columns and surfaces of another stove are less successful. They seem too spotty and possess too much the character of defective painting. In our judgment, in the pure majolica technique, painting panels or broadly modeled and therefore flat ornaments with a single color should be avoided. It is practically impossible to get an even surface of color upon large panels, since the porous coat of glaze dries the brush at once. The art plaques exhibited by Miss Drews, showing the art influence of the Industrial Museum, give a very pleasing impression at a distance, due to their dull colors. They are painted upon a somewhat yellowish gray enamel with conventional leaf and animal ornaments taken in part from old majolica work. The ground glaze is not completely opaque and allows the coarse, colored body to show through. From a distance, most of this work is very pleasing but examined close at hand it shows many technical defects which should have been avoided, as, for example, crazing, holes, bubbles and dull patches on many of the pieces exhibited.

The work of the painter W. Timm, done for the firm of O. Titel, is of great excellence and consists of flowers and birds painted in bright colors upon large faience tiles, which are used by this firm for stoves. In addition to these there are found artistic studies on tiles done in various manners. A woman's head is of especial beauty, painted by this artist on a large plaque for the fireplace in the exhibit of Messrs. Kayser & Von Grossheim which we mentioned before. Whether the insinuation that the background is not genuine, pottery colors not being used since the technical means of the majolica industry are not sufficiently advanced, is true, cannot be determined since the picture is hung too high ; at any rate it has lost nothing in its effect. The majolica work of C. H. Herm. Schmidt is confined to a few stove parts which are done in the Robbia faience style, consisting of colored fruit on a white or blue background.

The attempts of the Royal Porcelain Manufactory to revive the old majolica technique have been undertaken only during the last few months, and hence but a few pieces are shown. These differ so widely from other majolica work in their appearance that at first glance they seem to be something entirely different from what they really are and it is only by looking at the back that we can convince ourselves that the Velten clay has been used and the tin enamel has been employed in the background of the painting. The few pieces exhibited show the use of the rich color palette of underglaze painting on fine pottery and soft porcelain. At the same time they show the possibility of overcoming technical difficulties, which the painting on the soft unburned glaze offers, to such an extent that it has been possible to use the finest lines. In the majority of cases, as background for these bright colors of the Royal Porcelain Manufactory (apparently applied in relief), the coarse body of true majolica is not used but a much more permanent and more valuable material; *viz.*, a strongly translucent bone china. This can be covered with a relatively low fusing lead borax glaze. The first pieces of the kind were publicly exhibited at last year's Christmas Fair and received very favorable criticism. We do not think that the fine character of this body should be lost sight of when it is a question of doing artistic ceramic work. The soft porcelain for this purpose is deserving of more attention from the artists than has been given to it up to this time.

The pottery of S. F. Oest Wwe. & Co. shows a large variety of work painted under the glaze, partly on larger or smaller pieces of flat ware and partly on hollow ware. The firm with praiseworthy energy has encouraged this artistic development in majolica during the last few years. The painting executed on hard-burnt whiteware with metallic oxides and covered with a lead boracic acid glaze, is partly done by its own artists and in part by others. This factory has undertaken to furnish artists and amateurs, who are anxious to do majolica painting, with burnt pieces at a low price and, after they have been painted, to fire the colors and to apply the glazes. It would seem that many have availed themselves of this offer and that this plan should be recommended to other potteries so that artistic talent, which has up to this time held aloof from pottery, could be won. Thus we would help to raise German artistic ceramics which has fallen behind its neighbors, just as it is done by the same plan in England. It is certain that the charge of too little artistic encouragement in the clay industries would soon cease if this plan were carried out.

The stove of Schuppmann, in bright majolica colors, was mentioned in our report on the stove manufacture; we need, therefore, not speak further of it here. Although this young majolica industry has much to be criticized from a technical and an artistic standpoint, in the pieces exhibited, still there is great hope if only this present interest continues and is turned into the right path. We must always remember in judging these pieces, that most of them are merely experiments and that it is hardly possible for this industry, in the short time during which it has been in existence, to reach firm, complete, technical excellence.

CLAY WORKING MACHINERY

As the opportunity offers, many Berlin machine works build clay machinery, but only a few, in the present state of business, devote their entire energy to it as a specialty. Hence only one firm, the oldest of this character in Germany and on the continent, *viz.*, C. Schlickeysen, makes an exhibit. This display is the most varied and complete of any of its former efforts. It is shown in a special, large hall, and through its variety arouses a general interest—the activity and life in the building drawing many visitors. Naturally the majority of machines are for the manufacture of bricks since it is especially dependent upon various mechanical aids in preparing the body which it works. However, the other branches of the clay industry are not forgotten and we find many useful machines. The specialist sees here many improvements in the details of manufacture, which proves that this factory always strives to make its machines more and more complete.

Ten large machines driven by steam are worked alternately for many hours daily, according to the desires of the interested visitors. In addition to these are four machines which are worked by hand, also a great number of small machines and detail pieces. The necessary power is furnished by a 30 horse-power Corliss engine, from the Wilhelmshütte. Working the clay into solid or hollow bricks, is shown by a number of large machines. One large vertical machine, the so-called universal steam brick press, working with two dies, has a daily capacity of about 25,000 solid or hollow bricks. Two large horizontal machines are also exhibited, of which one forces out two clay columns at a right angle to each other while the other works with a single column, which, with a clay cylinder 500 and 400 mm. in diameter respectively, have a daily output of from 30,000 to 40,000 and 15,000 to 20,000 bricks, respectively. These horizontal machines, whose pugging shaft revolves more rapidly than that of any other machine, have had in recent years a great sale, well deserved on many grounds. Their compact construction, the ease with which all parts can be reached, the certainty in action of the feeding device, and the adjustable clay cylinder are undoubted advantages. In addition to the large brick presses there are three small ones (also of the horizontal type) in operation whose cylinders are 300, 200 and 100 mm. in diameter, which are used for making face, shape and square brick, stove tiles, flat tiles, drain pipe, stove tile bodies and flat roofing-tile. The machine making the latter is furnished with a Hausding roofing-tile cutter, which, compared with the old style, shows a marked improvement in that the tiles are much more easily transferred to the drying pallet. This is accomplished by pushing the finished tiles no longer on a smooth board, but on a frame which has a double set of rolls, and can be turned on a shaft, thus allowing an easy and rapid delivery without injury to the ware. A new repress, shown at this exhibition for the first time, driven by steam, is especially intended for forming sharp-cornered, dense fire-brick, and is praiseworthy on account of its great simplicity, which is always an advantage in machines. This machine is expected to press 800 fire-bricks an hour. Placing the rough brick under the plunger, which is driven by an eccentric, the delivery of the finished brick on a roller table is accomplished by a very simple hand apparatus which can be worked by children or women. The pressure is exerted upon the movable bottom plate of the mold by means of a heavy weight easily increased, which is worked with a 75-fold leverage and is lifted after each pressing. The pressure upon one brick can be raised to 5,000 kg. Of the larger machines, a double roll crusher of hard cast-iron rollers, and a patent pug-mill for preparing the clay to be molded on the press for a daily production of from 30,000 to 40,000 solid bricks should be mentioned.

A very strongly built portable repress worked by hand for making bricks shows the characteristic construction of this firm. In this the pressure is applid by means of a heavy fly-wheel and transferred through cams and wheels. There is also shown a roofing-tile press of the Boulet system with two alternately working bottom molds worked either by hand with a balance wheel or by power. Two machines, in operation, are shown for the manufacture of glazed clay pipes, a branch of manufacture constantly gaining in importance in the construction of the sewer systems in the larger cities. The larger one of these makes sewer pipes with an inside diameter up to 600 mm.; the smaller, worked with a balance wheel or belt, makes pipes up to 280 mm. outside diameter, with pressed flanges. Both are of the same construction, consisting of a perpendicular clay cylinder mounted on an iron framework from the bottom of which the clay passes out through a round opening; in front of this opening the die for the flange is placed. After the flange die has been filled the pipe is forced out which, as it comes out, rests on a platform balanced by weights to correspond with the weight of the pipe. When the latter has been cut off with a wire it is taken away upon this platform furnished with wheels for the purpose.

For smaller firms, clay works, stove tile factories or potteries, there are also shown some machines worked by hand-power. There are roll crushers, pug mills, auger-presses for tiles, cornices, and architectural pieces, which correspond, in their construction, mainly to the larger machines employed in the manufacture of bricks. These furnish cheap and desirable devices for those small factories that are still accustomed to prepare their bodies by hard hand-labor.

PORCELAIN AND FINE POTTERY

Although the raw materials for this branch of the Berlin industries, the fire-clay, kaolin, feldspar, and flint, are not to be found in the immediate neighborhood but must be brought from a distance, still, the manufacture of porcelain is especially well advanced and forms an important and well-known branch of the industrial life of the capital. The exposition gives a very good picture of what Berlin is able to accomplish in this direction since all the porcelain factories with but one small exception, are represented. They are six in number and in addition there are two porcelain painting establishments and one fine pottery which exhibit. Of these the Royal Porcelain Manufactory first takes our interest. It shows not only its artistic progress in decorated table service, but also a fine assortment of such objects as are used for technical, pharmaceutical and chemical purposes. In exhibiting the latter, something of the exclusive character shown at the former expositions is lost. However, we would be sorry not to have it so, since it is especially in this branch that it has done so well, both as regards quality of the porcelain, and in the overcoming of the technical difficulties in making pieces of a size not attained by any other factory. As to the quality of the porcelain made by the Royal Porcelain Manufactory, nothing new can be said. Of course, it is less translucent than many of the Bohemian and French porcelains, but it is better than these in its ability to withstand blows or sudden changes in temperature. It is to this quality that the world-wide reputation of its chemical and pharmaceutical articles is mainly due; these articles for technical and scientific use are partly represented by objects of great size, such as round, oval and quadrilateral dishes, chlorine jars, separating pots, filters, sanitary ware, etc.; of an extraordinary size, considering the nature of the material, partly by smaller utensils of a more complicated form, such as U-tubes, retorts, stills, narrow-necked flasks and other articles, which show how the difficulties of shaping have been overcome successfully. The large, artistic, purely decorative pieces are represented by a large vase of amphora-like shape consisting of several pieces whose joints are bound with richly ornamented bronze bands. A large painted table top is also shown. The majority of pieces consist of richly decorated show pieces and also of useful articles, especially in the rococo style, which seems to be specially adapted to hard porcelain; also the well-known pleasing small figures, table services and vases, which testify to the technical skill of this factory in the making of delicate, pleasing shapes. Considered from this standpoint, especially noteworthy is a little bowl, guarded under a glass bell, which is surrounded, for its ornamentation, by a very delicate wreath of roses, made by hand. In addition to the well-known decorative motives the factory in recent years has again taken up the Meissen onion pattern, painted in blue underglaze colors. The attempt to decorate porcelain with colored glazes is shown by a number of small, mottled tables and a collection of 100 porcelain tiles which show the color shades obtainable in this manner. A new, simple method of decoration, quite pleasing in its effect, has been tried on little dishes, bowls and other articles. It consists of piercing the sides of the piece according to a simple pattern and then closing these openings with glaze. In this manner a pleasing contrast is obtained between the more translucent, only slightly clouded, glaze parts and the less translucent porcelain body. The experimental work, aiming to extend the artistic field of the Royal Porcelain Works to other materials than hard feldspar porcelain, namely, to the manufacture of majolica glazing on bone china and fine pottery, has been mentioned above in connection with the Berlin majolica works.

Another exhibit of high character is that of the Berlin Porcelain Manufacturing Co., formerly A. Schumann, whose products have long been held in good repute. The standpoint which this factory seems to maintain is entirely different from that of the Government Factory, which is expected to develop the industry in an artistic direction. Here it is a question of sober business interests which must mainly be kept in mind and the artistic side must therefore step in the background. In spite of this, however, the exhibit of the Schumann Works shows that both directions, within certain bounds, can be united and that it is possible, without preventing the sale of the ware at comparatively low prices, to give useful articles an artistic appearance both in form and decoration.

The firm indestructible decoration of the beautiful, translucent, technically perfect porcelain by means of underglaze colors, is shown not only by the blue Meissen onion pattern but also in a complete very pleasing service done in cobalt-blue and chrome-green leaf ornaments, designed by Luthmer. The painting with muffle colors also permits the use of pleasing flower decorations. A very beautiful piece with an Egyptian style of decoration in harmonious color shows this. Less successful, however, is an attempt to use the Persian shapes and decorative motives. A tea service, two examples of which are shown, designed by Genick, demands too much in its form for the technique of porcelain to find imitators. Still the factory shows that it is by no means held back by fear of great technical difficulties. A large vase of classical form, decorated with biscuit ornaments, shows that the factory does not lack the artistic power to make purely artistic products together with those intended merely for daily use.

The firm of Opdenhoff Bros., in Moabit, exhibits common, solid domestic ware, of a simple form and without artistic decoration. A. Schomburg & Sons exhibit technical products, especially telegraph insulators and evaporating dishes. Apothecary articles, in a slightly translucent body similar to the old sanitary porcelain, are shown by W. Haldenwanger, in Charlottenburg. The young firm, Lange & Co., the Berlin Porcelain Flower Works, shows an industry entirely new to Berlin, the manufacture of porcelain flowers. Considering the short time which the establishment has been in operation it shows very good results in the manufacture of roses, faithfully imitating nature both in form and color. There is not much to be said about the porcelain decorated by china painters from various sources; it consists of table, tea and coffee services, toilet sets for private houses and for hotels, painted with flowers, vignettes and firm names which does not rise above the general average of this style of ware.

The firm of S. F. Oest, Ww. & Co. is the only one exhibiting whiteware. Its work is mainly devoted to white and plainly decorated pottery as a substitute for porcelain; white mottled pieces and those decorated by means of stencils are only sparingly shown and do not appear very favorable in their present surroundings. The yellow body, with its somewhat clouded strongly blued glaze of little brilliancy and which is also crazed, is not free from blotches; it allows of no mistaking it for porcelain.

In quantity and quality the artistically handled pieces and plaques are much better and of these quite a number of pieces are very successful in decoration and choice of colors. Entirely aside from the artistic standpoint and considered only from a technical one a good deal can be criticized. The colors seem dry in the majority of pieces, under the thin layer of glaze and are too little dissolved, and hard. Still we will say that certain pieces brought to the exhibit later, which represent the latest work of the firm, show marked steps in advance and are of great promise. In our judgment this exhibit of pottery, apparently intentionally crazed, cannot be considered in harmony with the interests of the industry. Nevertheless, in recent times we are taught, from an artistic standpoint, that the so-called craquelé (that is, a regular arrangement of the crazing upon the surface) is a desirable method of decoration. This may be true with the vitrified body of porcelain, but for the porous body of whiteware, crazing, whether it be in a regular or an irregular pattern, is always an unpardonable technical defect as it prevents the practical use of such a piece. Although these art plaques and vases, as a rule, serve only decorative purposes, in our judgment, the use of the same should not depend upon the character of the decoration or the crazing of the glaze.

The Clay Industries on the Island of Bornholm

STANLEY G. BURT, TRANSLATOR

The Danish Island, Bornholm, is located in the Baltic Sea, 6 German miles from the southern coast of Sweden and 12 miles in a direct line from the Pommeranian coast. It holds in its bosom, in spite of its limited area of only 10.75 square miles, such a wealth and variety of mineral treasures, valuable to the clay industries, and such a well developed clay industry, that it might prove of value to the readers of this journal to devote an article to the conditions prevailing there. A mention of the geological and industrial development of this island may also be of practical value, especially to the North Germans, since such a mineral wealth as found here is not found in the North German plains, and importing these raw materials should not meet with insurmountable difficulties since there are a great number of good ports near the mines and good means of communication upon the island. The writer had the opportunity last summer of visiting this island, interesting also in regard to natural beauty, and he will give here the observations made at that time.

The island, which forms a fairly regular rhomboid, is characterized in the greater northern half by a granite plateau, which reaches at its highest point a height of about 150 or 180 meters above the sea-level, and falls away in perpendicular and wild cliffs. The interior of the northern part shows granite at the surface, and is but sparingly overgrown as it furnishes, for wide stretches, scarcely soil enough for the growth of heather. It is only in the numerous valleys leading down to the sea that we find a rich soil farmed in a progressive manner and which furnishes rich returns. The southern part, more level and sloping toward the sea, is productive and well wooded. The granite is here covered by the chalk formation and on the west coast there are also products of the coal formation with rich beds of sandstone, marl, plastic and shale clay and also lignite. The island has on its west coast two good ports — Rönne and Hasle; on the east coast there are five — Sandvig, Allinge, Gudhjem, Svanike, and Nexo. The northern part of the island furnishes granite for export, as sidewalk blocks, coping stones, paving blocks and it also produces kaolin and feldspar. The southern part furnishes the material for a lively terra cotta and faience industry, the manufacture of fire-brick and common brick, and even of Roman cement.

The very hard coarse-grained granite, consisting of flesh-colored feldspar, flint and black mica, is mainly mined on the northern point of the island, at the Hammerberg, in the neighborhood of the extensive ruins of the Castle Hammershus. It is worked in the quarries into sills, and flagging and paving blocks, and is shipped from the ports of Sandvig and Allinge, mainly to

Denmark and Russia. On the eastern coast, in the neighborhood of the little port Gudhjem, there are veins of flesh-colored feldspar in the granite for which a market was sought recently in Germany in the porcelain and whiteware industry. The fact that its introduction did not meet with immediate success was due to its content of black mica, inclusions which might prove very serious for these industries. However, recently, beds, of great purity, have been found, which are said to equal in quality those of the Swedish and Norwegian feldspar. At any rate the deposit of spar must be very extensive, since the road leading from Allinge to Gudhjem, near the sea and about a half mile from the latter place, is almost entirely made of red feldspar which contains inclusion of quartz and mica. Although this spar, found on the surface at Gudhjem, is not of sufficient purity to be of value to those branches of the clay industry which place special importance upon the whiteness of their product, still it is worthy of notice by those who could use a less pure but cheaper material; for example, the manufacturers of mosaic tiles, sidewalk or paving brick, and artificial stone bodies.

Southeast of Ronne, the capital of the island, the granite is covered by tertiary formations of sand, loam, and plastic fire-clay, and is weathered to a great depth. This furnishes the basis for the extensive mining of kaolin. There are here two kaolin washing establishments, the larger of which is owned by a company at Copenhagen, called "The kaolin-industri-selskap paa Bornholm." In this establishment, which is managed by a German, the kaolin, after clearing away the surface soil to a depth of from 2 to 5 meters, is mined in an open pit 20 to 25 meters deep. The crude kaolin, loosened by picks and shovels, is hauled by a steam hoist, to the top of the pit, on an inclined track over 200 meters in length, dump cars being used, which empty their contents directly into the slumming machine. The water-level is kept low by means of a pulsometer placed in the pit, the water coming from rain only. This machine is fed with steam from the boilers of the hoisting machine, which is at some distance, and which, compared with the double action steam pump formerly used, has proved very successful under the peculiar conditions obtaining here. The washing of the crude kaolin with water is done in four large stamp mills and two slumming agitators, of which the first wash about 250 and the latter 150 cwt. The kaolin slip flows from the agitators into a common receiver, from which the coarse sand which continually settles out is being constantly dredged with hand shovels, thrown on cars and at once dropped back into the pit. Further along in the crooked receiver which has a slight fall, the finer sand settles out, and is being continually dredged out and carried off. This kaolin slip, freed from the greater part of the sand, now flows into a large flat basin, in which the last of the fine sand is allowed to settle out. From this at intervals of a few hours, the slip is drawn into six large, walled settling basins, about 30 meters long, 20 meters wide, and over 2 meters deep. Here it remains until completely clear, which takes more or less time, depending upon whether the weather is windy or not. The clear water is then drawn off through zinc pipes which are connected with the bottom draining pipes by means of rubber tubes, and can be lowered with a string to the surface of the kaolin slip. The water in summer, when there is a scarcity, is returned to the well from which the slumming agitators are supplied. The soft slip remaining in the settling basins is allowed to flow off to a cistern and from here is pumped to the filter-presses. The press and drying house is a large two-story building, having in the lower story the stock room for the finished kaolin and the steam engines, with the four force-pumps driven by them. The upper story contains in one room eight large filter-presses, in another the drying-room for the pressed cakes. The force-pumps in the lower story, which work under a pressure of 8 atmospheres, force the kaolin slip into the filter-presses above them. The fairly firm cakes, about 3 cm. thick, which form between the press cloths, are placed on pallets which can be set on top of each other. The drying space is provided with Venetian blinds and the cakes remain here till perfectly dry. In order to facilitate the handling of these pallets from the filter-presses the dry room has a track throughout its whole length. Transferring the dry kaolin to the store-room is done by simply dropping it through holes in the floor into the bins below; 40 per cent of finely washed kaolin is obtained from the crude material. It is remarkable for its very white color but takes a faint yellow tinge in a hard fire. According to tests made some years ago by Dr. Bischof, it is equal to or excels the Zettlitz kaolin in its ability to resist heat. It is sold to the paper, ultramarine, porcelain and whiteware industries of Russia, Denmark and Germany; also to Holland, Belgium and France. It is transferred the short distance of 3 to 4 km. to the port of Ronne in wagons over a good road.

A second larger establishment, also owned by a company of Copenhagen capitalists, is located on the west coast between Ronne and Hasle, where massive beds of shale clay are found, which contain thin veins of lignite. This is the brick and fire-clay works "Hasle kul og teglverk." Coal has been mined here for a long time, but since the quality is ordinary, it could only be used for domestic use on the island. Therefore the old coal mine was given up, and at the present time mining of fire-clay and brick-clay is mainly carried on. The former is exported, and at the same time a large brick and fire-clay factory is being operated. The coal obtained is merely the small quantity which, found in thin veins, is brought out with the clay. The clay bed, which is opened in a pit to a depth of about 20 meters, forms a firm shale-like body with many plant impressions, coal stains and thin coal veins. The upper layers are quite fusible and are suited for the manufacture of bricks, while the lower show marked refractoriness. The brick-clay brought from the pit on an inclined track is pulverized by a disintegrator, and then soaked for many days in the basement of the machine house. It is now raised by an elevator to the large Schlickeysen brick press and worked into bricks, which are burnt in a 16-chamber continuous kiln. The brick business is carried on partly with Swedish labor, partly by a colony of Lippe brick-makers each under the direction of its own foreman. The fire-clay which comes from the lower strata is also a shale clay and is worked from a shaft which is connected with the pit by drifts. After it has weathered for a long time, 25 per cent of burnt clay, obtained partly from the kiln waste and partly by special burning, is mixed with it. This is now worked in a pug mill and molded by hand into fire-bricks, which, after being repressed, are burnt in part in a continuous kiln, while part of the output is burnt in a dome kiln. The fire-bricks thus made stamped "Hasle" are mainly sent to Russia where, owing to their great refractoriness, they compete successfully with the English and Scotch fire-bricks. From one strata a clay is obtained which vitrifies when burnt and which a few years ago was used for making glazed water pipes. This manufacture has, however, been given up as it did not pay to compete with the English product. The raw material which was thus used is now merely exported in the pulverized condition and, owing to its ready vitrification and great stability in the fire, forms an ingredient which, when used with other materials, is suitable for making the black blue paving brick now being manufactured in the neighborhood of Stettin. These "blue" or "iron bricks" have been introduced in recent years in the cities along the Baltic Sea, and also in Berlin, for pavements. This material might be used in other places which have water connection, for paving purposes, especially since the transportation facilities are very favorable; the establishment of the "Hasle kul og teglverk" is connected with the port of Hasle by a track.

Another branch of the clay industry very interesting, owing to its individuality (the manufacture of terra cotta) has its home at Ronne, a little city of 6,000 inhabitants, of whom 200 to 250 are employed in the potteries. Their popular products are not only sent to Denmark, but find purchasers in distant lands. These reproductions of antique forms have been well-known to our readers, for a number of years through their delicate forms and pleasing decorations, and are known under the collective name of Ipsen terra cotta. The manufacture of these articles had its origin on the island of Bornholm, since its founder, of the well-known firm, Ipsen Wwe., of Copenhagen, is a native of Ronne, who later went to Copenhagen. This factory still obtains its raw material from the island. There are now in Ronne three factories occupied with the manufacture of this ware: J. Hjorth,

E. F. Sonne, and Windrich. The clay used in these works is found in the hills along the shore and consists of a plastic clay highly charged with streaks of mica and a red ochre. The former burns to a fine buff, the latter to a yellowish red color. Since the manufacture does not consist in the production of large quantities, but of articles of artistic value, for a small number of patrons, it has taken the character of the small shop industry. This, however, affords the proprietors a more complete devotion to the artistic character of the production. The manufacture is considered by the artistic circles of Copenhagen, as being characteristic of Denmark and they give it every assistance.

The technical side of the manufacture can be understood from the following steps in the process. The clay brought from the pit to the factory is first washed by being softened in a plunger and is then passed through a fine sieve and allowed to settle in wooden tanks. The slip thus obtained is freed from water by a small hand filter-press, is brought to a workable condition by pugging, and then stored in the cellar till needed. The pieces are formed either in plaster molds or are thrown on the wheel; when the piece is leather-hard it is turned on a lathe and polished with a piece of horn. The handles and feet, which are also made in plaster, after they have been smoothed, are attached to the pieces by roughening the joints with a knife, moistening with water and sticking the parts together by means of soft clay. The joint is, of course, trimmed afterwards with a modeling tool. Of especial interest in making the pieces is the use of both bodies in one piece, the yellow and the red; thus, often where the main color is red there is a broad yellow band at the middle, or a yellow band in a red piece. The decoration is applied on the band. The molding of these pieces is done as follows: At first only the lower part is pressed in the plaster mold and the top evenly cut off; to this is attached, by turning, the other colored clay and at the height desired for the band this is cut off; the upper part is then finished with the first body. The whole piece is worked on the lathe like the other ware. The terra cotta is burnt in saggars in a horizontal pottery kiln fired with wood. The decoration consists in reproducing antique shapes either by black designs on the matt clay ground or in allowing the drawing to remain outlined in the clay color upon the black colored surface of the piece. In the latter case the outlines of the figures and the draperies are incised with a needle; in the former it is painted on in black lines. The black covering, the drawing, and the color painting are done partly with vitrifying porcelain colors which are fired in the muffle; in part of the ware, varnish colors are used. The latter is applied, especially in the case of decorations, in bright colors in the Egyptian style and in flower painting. The trained artists for this painting are mainly natives of the island. All painting is done free-hand; the less skilled workers, however, trace the outlines first. The use of stencils has not been successful, although often tried, because it does not give such fine work. In addition to these imitations of the Etrurian, Greek, and Egyptian vases, both in form and decoration, there are also copies of statues and groups, partly from antique and partly from modern plastic works but always carried out on a small scale. Copies of Thorwaldsen's sculptures take the leading part and are especially encouraged.

Another branch of the clay industry that is of importance, for the island, is the manufacture of ordinary pottery, which is carried on in Ronne by eight potteries. These are mainly of small size, the largest being that of W. Wulfsen & Son, employing 25 people; however, the production is large enough not only to supply the island and send a part to Denmark, but also to seek a market in Pommerania. Competition, with the much cruder but cheaper German pottery together with the duty, has made the export to Germany very difficult. The production is confined to household pottery, — tea and coffee pots, milk and water pitchers, flower pots and such things. As a whole the products are pleasing in shape, decorated in relief or with colored glazes of a pretty, agreeable appearance. The undecorated, unskilled pottery of Germany seems unknown on the island; even on the flower pots one sees everywhere at least the attempt at decoration, with colored rings, strings of pearls, reliefs and glazes. In the household ware the shapes used in English china seem to predominate; where any individuality in the shape appears, as, for example, in the above-mentioned terra cotta, the influence undoubtedly comes from the Thorwaldsen Museum. The relief decorations, either applied or modeled, are almost without exception copies of Thorwaldsen's sculptures.

The raw material used in the faience factories at Ronne is a yellow burning clay free from lime, like the German lignite clays. In order to enable it to hold a tin enamel and easily fusible lead glazes, 20 per cent of chalk from the island of Möen is added. The clay, in the preparation of the body, is washed in a plunger driven by steam; the chalk is ground fine in a little drag mill; both of these ingredients are then united in the liquid form, passed through a fine screen and allowed to settle in a tank. The bottom of this pit consists of a copper plate which is heated by the exhaust steam from a 4 horse-power engine, thus drying the mixture. The pieces are made only in plaster molds. An opaque tin enamel is used especially on the inner surfaces of hollow ware, which, in the biscuit fire, assumes a light yellow-brown color. A mixture of minium and sand is also used for surfaces decorated in relief. In addition to these there are used colored glazes obtained by adding copper scales, manganese, iron oxide and smalte to the previous blends. The glaze materials are ground in a small drag mill of about 1.5 meter diameter with two three-cornered stones. The hard sandstone which is used for the bottom of the mill and for the grinders is found in the southern part of the island. The biscuit and glost firing is done in saggars at the same time, in a horizontal pottery kiln, the glazed ware being placed in the cooler portions.

The manufacture of bricks, although there are large and well-arranged brickyards in the neighborhood of Ronne and Hasle, is only of local importance. Their field consists merely in supplying the naturally very limited demand on the island for artificial building material for which they compete with the abundance of natural building stones found here. It is, therefore, surprising under such conditions to discover, in the city of Ronne, some very successful attempts at true brick buildings.

This proves that this branch of the clay industry is also carried on by intelligent hands.

Like the manufacture of bricks, that of Roman cement, which is carried on by two factories in Ronne, and also by a few small works in the southern part of the island at Aakirkeby, is merely of local importance. Still it is interesting to know that in a district so small and with a situation almost completely cut off from the rest of the world, especially in winter, we should find an industrial activity carried on in such varied forms and with such intelligent and artistic skill.

The Exhibition of the Union Centrale des Arts Decoratifs, in Paris, 1884

STANLEY G. BURT, TRANSLATOR

The Exposition which was held in Paris, in the Palais de l'industrie, was the work of the activity of the above-mentioned society which aims, by means of annual expositions, to present the discoveries and advances made in the separate industrial branches and thus to offer a spur to the national industries for new achievements. The exposition of this year is the eighth of its kind and includes products of wood, stone, burnt clay and glass. It is, however, really a ceramic exposition; the products of wood and stone and also those of glass, are more in the background and the ceramic products predominate, from brick up to porcelain. The number of ceramic exhibitors is 199, who are mainly French. Only here and there does one find a foreigner and these are those who have their own salesrooms in Paris, thus gaining certain rights of citizenship. These are seven English firms, two Italian, two Austrian, one Swiss, and one from Holland.

Let us enter through the dusty, insignificant entrance into the magnificent building of the industrial palace and examine the products exhibited, beginning at the bottom with bricks.

The exhibitors of brick are mainly members of the Union Céramique et chaufournière, fifty-one in number. In addition to these, however, we find examples of this branch among other exhibitors. The bricks, roofing-tiles, paving-tiles, and glazed bricks shown, come mostly from those manufacturers who have their market in Paris. They all seem to be made from much the same material of a strong red color, very porous, like our Rathenow products. The manufacture of face-brick in France plays an entirely different part from what it does with us in Germany. Brick fronts proper are but little seen in Paris. In all the larger buildings, especially the public structures, the cheap and very appropriate limestone is used in Paris for façades. The manufacture of face-brick, corresponding to the demand, is but little developed. Of some twenty exhibitors, who exhibit brick which might be called face-brick, there is no sign of an effort to fulfil the conditions, often very strenuous, demanded by our architects in respect to color, density and character of the surface and shape. What is shown are good bricks as respects color and shape, but they are, by no means face-brick as we understand the term. Moreover they do not become so by being covered with a colored glaze, since we know positively that a soft lead glaze, upon porous clay, cannot withstand the weather but will peel off. The color palette for glazed brick here shown is quite comprehensive; it includes brown, yellow, blue, green, and even chrome-red colors; where the underlying red would alter the colors in part a white slip is used; in part they are made opaque by oxide of tin, and in some cases the glazes are applied on a facing of kaolin body. Emile Müller, at Ivry, near Paris, Kaltenheuser, Léon Parvillé, in Paris, and some others show products of this kind. These, by means of their brilliant colors, are more apt to catch the eye of the public than to impress the expert. There are also represented some manufacturers of brick machines and mills. Products of this kind, which come from Joly & Fourcard, in Blois, and Jannot in Triel (Seine & Oise) do not offer anything of special interest, so we need not notice them. Of the engineers, C. E. Bourry, of Paris, who exhibits in use a Schwandorf gas kiln of small size, should be mentioned. This kiln produces very good bricks, which are made and dried at the exposition. Boulier should also be mentioned who shows a pyrometer (of which I will speak later) in connection with this kiln. The exhibition of fire-brick and common salt-glazed, stoneware pipes and vessels, also furnishes nothing of especial interest. Only in the case of large show pieces and jardinièrès for the garden the use of a red glaze colored with "pink" is noteworthy, which seems to be pretty generally used. Such things are shown by Clement Massier in Golfe Jean (Alpes Maritimes), and can also be seen in many other places.

As specialties for building purposes there should be mentioned the products of François Perrierè, consisting of arch pieces to be fitted to iron; these arched blocks are made on a brick machine, up to 2 meters in length, and can at once be laid between T rails and thus form a fire-proof ceiling.

More impressive than the brick products is the exhibit, beautiful and very extensive, of terra cotta figures, in the making of which Paris is so expert. They are mostly small figures, modeled free-hand, and at times of different colored clays or of clays to which color has been added, and generally represent Parisian characters. That this industry is of no little prominence is proved by the fifteen to twenty exhibitors of these products; especially noteworthy for this kind of work is a potter, Blot, in Rosendael-les-Bains, near Bolougne. His products, seldom over 20 cm. high, but sometimes quite extensive, are most charming groups, showing peasant scenes, generally fishermen or peasants. The separate persons are most charmingly modeled and the animals added characteristically, the whole impression being so agreeable, that it always gives me pleasure to see the ware again; it always seems new although this type of ware was shown in Vienna, and at the last Paris exposition.

The French art faience is also interesting (useful articles are hardly shown at all) in its many varieties of body, of colored glazing, and in its whole effect. Here we again find a lot of old friends who have not changed materially, only that in a measure (in their artistic handling) they have left ceramics, for what I know not. Of the old ceramic workers we find a number here, first Claude Achille Barbizet, with his reproductions of the Palissy faience. If one compares the work of this artist with the old work of Palissy, which is kept in the Louvre, we will find a deceiving likeness between them; the later work, however, has gone badly astray. When one sees vases upon which have been placed little animals, beetles, lizards, frogs, etc., as was done in the Palissy technique, they may be considered justifiable, but when one finds trees and houses growing out of the depths of the vase and endeavoring to overtop it in height, it is certainly bad taste; nothing worse than this could be imagined. Of such work there is a great quantity. Ginori, in Doccia, imitates the Italian majolica in very fine manner. Less fine, in fact ugly in decoration, is the porcelain made by this firm. Joost Thooft & Labouchère, in Delft, imitate the old Delft faience; the ware looks very pretty, partly in green and partly in yellow enamel, painted with cobalt-blue upon the enamel entirely in the form and in the characteristic decoration of the old ware. The body consists of a clay containing lime just as does the old ware of this kind. We again find Doulton with his products—in part brown stoneware vessels on which a decoration of landscapes, hunting scenes, or animals is brought out by incision; this is then brought into more prominent relief from the surface by means of a darker color. He also shows decorated balustrades, columns, banisters and other building terra cotta of stoneware decorated in this characteristic way with pale colored glazes. Our Mettlach firm of Villeroy & Boch shows in its stoneware pottery as well as in its building terra cotta, stronger colors and a more pleasing product. Doulton & Co. have remained stationary at the point they had reached at the time of the Vienna exposition. At that time if they attracted attention it was due to the newness and individuality of their product. Now, however, the gray-yellow, gray-green, and gray-blue color tones leave us unmoved. The same is true of the wall tiles painted under the glaze in a gray-brown color covered with a yellowish gray glaze. They appear insipid, truly English.

We find a number of large vases shown by Schopin, of

Paris, decorated in the most pleasing manner in heavy strokes of slip painting. The ground is generally held in a gray tone, and the large flowers are applied in bold strokes with colored slip, appearing in a kind of relief, permissible in this technique. This mode of decoration will always have a certain value. O. Milet, in Sèvres, shows pottery decorated with various beautiful, colored glazes, placed alongside of each other and over each other, thus giving a flame effect. Characteristic is the use of gold and silver flakes which float in the glaze—that is, they are fused together with it and reflect in varying shades the different colors, according to their depth in the glaze and according to their position. The above-mentioned firm, like many others whom I will mention later, has made experiments aiming to produce a red glaze by the use of cuprous oxide. These experiments have not led, however, to a clearness of color worth seeing. Of the twenty to thirty pieces of this kind exhibited, only a few show the character of the cuprous oxide color in its richness; the rest (probably three-fourths) have a black color with only here and there a trace of red. Jules Löbnitz shows a great number of his beautiful products, which aroused attention at the Paris exposition. These are generally stoves, in the Gothic and renaissance style, door and window trimmings, wall tiles and other architectural pieces. These are colored with beautiful, mostly tin enamels, whose color divisions are brought out by deep black lines in the body. The glazes are smooth and brilliant, generally free from crazing, which is quite a rarity in French faience work.

D'Huart frères, in Longwy, show a number of their products, generally ornamental pieces but also domestic ware, which are decorated in a manner characteristic of this firm. The outlines, birds, flowers, butterflies and other things are printed upon the surface of the body with an oil color or else they are painted on. In the divisions thus made, enamels and transparent glazes are applied which are kept apart by dark-colored lines and then further decorated with overglaze colors. Often a red color is used for the ground. The faience works of Gien show wall tiles done in similar manner, generally of Persian design, which are in part produced like the preceding ware, and, in part, decorated with colored glazes over the generally blue printed pattern. Gien shows only this one branch of its great industrial activity. The manufacturers of Saargemünd and Digoin, Utzschneider & Co. show, in addition to smaller articles, a great number of larger wall tiles. These are partly decorated in relief, covered with colored glazes so that the thicker or thinner layers produce the shading, partly in the Deck style, consisting of small divisions obtained by low slip dams, which are painted and then covered with colored glaze. Especially beautiful in its coloring and in its whole execution is an almost life-size picture of Saint Catharine. The products of these firms (stoves, fireplaces, large animals, etc.) in colored glazes are almost all crazed.

I do not intend to mention separately the products of all the makers, of the amateurs, of the institutions for art and industry. This would carry us too far and as it seems to me would be without value. However, before I come to the most interesting part of the exposition, the products of the manufactory at Sèvres, I wish to mention one more man, who is not only a manufacturer but also an artist, and who has exerted no small influence on the development of the French pottery industry, who, even yet, assists the French government factory, with his technical and artistic ability and advice; I mean Theodore Deck. The work of Deck has a characteristic richness, and can be distinguished without difficulty from the numerous examples of the work of those who strive to imitate his technical and artistic manner. The Deck faience has glazes, transparent, beautifully colored, free from crazing and perfectly clear. Especially rich is the turquoise-blue, the violet-brown and the red which he uses, and which he knows how to mix with the other colors of his palette in a masterly manner. With these colored glazes he undertakes mainly flower pieces, birds and butterflies, painted upon large tiles and vases. The technique employed is an entirely distinct one. The outlines are marked, with a mixture of glaze, body and color in little thin ribs, built up on the body to a height of about 1 to 1.5 mm. Thus divisions are made which correspond to the "émail cloisonné," of the Japanese and Chinese industries, with this difference, however, that here the outlines are of a ceramic body, while those are of metal. The surface divisions thus formed are painted with colors and shaded, the colored glaze being then applied as a thick layer, and fused. The glaze is often underlaid by thick gold leaves which increase the brilliancy of the colored glaze and give it a characteristic color. The round basins, vases, wall tiles, friezes and similar objects are thus made always by hand though it would be simpler and less costly to cut the cloisonne work in the molds and thus press the lines on the body. The cost of the production of this ware is therefore, pretty high, but it has an extraordinary charm and every piece can be considered as high art. Deck lays stress on having his work done only by hand, each piece being unique, not like the productions of a large factory; thus he gives to the pieces a high value as art products. The head, in life-size, in matt brown color upon a gold ground by R. Collin, the large character figure by Anker, and the flower painting by Regnier are productions of high artistic value.

The body used by Deck is made from a white clay containing lime which allows the light to penetrate to a certain depth; the glaze, according to his own statement, is a leadless one. The characteristic, transparent, magnificent red which he uses is an engobe of a clay with a high percentage of iron, which, owing to its lime, has a translucency and a semi-transparency like a porcelain body. The Deck technique has induced many manufacturers to do similar work but their productions have not the charm which causes us to wonder at that of Deck. We find, for example, such articles shown by E. Lachenal and Fargue & Hardelay.

However, Deck has not remained at a standstill with his faience but has tried with equal success the manufacture of porcelain. Of the work which he shows in this material, two styles are remarkable and in their manner new and charming. These are articles in a kind of pâte sur pâte and copper-red porcelain. The pâte sur pâte work differs from the like work of Solon of the Limoges factory and of Sèvres in that the painting with slip is not applied upon the colored body, but over the glaze which is generally a beautiful Seladon-green. This work, which I had an opportunity to see, consists of a porcelain body applied on the raw glaze and then covered with a white glaze. The extremely tedious work done by artistic hands has a magnificent appearance,—the painting not only seems to float on the glaze but it allows the light to penetrate beneath it. Deck was the first of the French manufacturers to succeed, a few years ago, in the production of the difficult but magnificent copper-red porcelain glaze in the glost fire,—the *rouge flambé*. The fifty pieces which he shows give the red in all its characteristic shades and colors which are individual to it and make it so magnificent.

The private porcelain industries are represented by a number of Limoges and Vierzon factories. The Chambre Syndicale de Porcelaine du Limousin has a collective exhibition of the Limoges factories; in it fifteen factories are represented. The porcelain of these factories, as far as the body goes, is, on the whole, more beautiful than the German. This is due, on the one hand, to the greater purity of the raw materials which are found at Limoges, on the other, to the high percentage of feldspar often noticeable, which the body possesses naturally. In Limoges, weathered pegmatite is mainly used which contains in itself the ingredients of porcelain, clay, feldspar, and flint, it being simply ground. The body used at Limoges, since it is made up of natural stone, contains varying amounts of the separate ingredients of porcelain, the percentage of feldspar going up as high as 42 per cent. As a result it is remarkable for its extraordinary transparency. It is, however, more brittle and more liable to be broken by a blow or sudden heating than the majority of the German porcelains which have a higher percentage of clay. The pieces exhibited are mainly decorated services,—tea and coffee sets, toilet sets, and things necessary in daily household use. The shapes, as a rule, leave a good deal to be desired. The decoration is delicate and often tasteful, but at times it is somewhat odd; there are, for example, chickens crawling from eggs, other birds, fishes and amphibian animals painted upon plates, which are not beautiful, nor do they increase one's appetite; still one sees such things frequently on the French porcelain but there are found also actual defects in the decoration shown. In the collective exhibit, in the most prominent place, there is for example a little coffee service in a costly satin case—it must, therefore, be something especially good. It is richly covered with relief decoration and would be very good if one could only see of what material it was made, but it is gilded so completely inside and out, that only by breaking one of the pieces would it be possible to determine what the material was. The Limoges factories have also given much attention to the artistic direction in the technique for which their material is especially adapted, the painting in pâte sur pâte. They show vases and basins done in this style, in blue, green, gray and red color tones of the body, the painting generally representing figures, being applied on the colored ground in low relief in white or pale rose color, the whole being covered with glaze. Almost all of the exhibitors have tried this technique (first practiced at Sèvres) with more or less success, but the pieces are often, especially in the most difficult part (the figures), quite defective. None of the factories have reached a stage such as that shown by Solon in the upper rooms of the Industrial Palace, who, since his departure from Sèvres, has been working in the less suitable English material.

In addition to the Limoges collective exhibit, a number of other manufacturers show their product; I will mention only Hache & Pepin Lehalleur, in Vierzon, and Haviland, at Limoges. Especially noteworthy from the first factory are the extraordinarily thin, transparent coffee cups, which, in order to increase their transparency, are pierced in definite designs. These perforations are filled with glaze. Haviland, who is especially distinguished from the Limoges factories by articles of artistic value, has, like Deck, Milet and Sèvres, also made experiments aiming to produce the cuprous-oxide red in the hard fire. Of the pieces which he exhibits there are only two cylindrical ones which show a fine red. The rest of the pieces are black, or blackish green, and should be considered as failures not worth exhibiting. All these efforts, probably even those of Sèvres, to produce this red, should be considered as yet mere experiments, since only now and then they lead to results, there being but little certainty in the production. I cannot mention separately the various exhibitors who have decorated their porcelain and faience in various manners, and will confine myself to the most prominent and most worthy exhibit—that of the factory at Sèvres. The exhibit of Sèvres is by far the most comprehensive, and includes a number of rooms of the upper story of the Industrial Palace. The catalogue of these contains 750 numbers.

The first room which one enters contains an exhibit of the designs by the artistic director of the institution, Mr. Carrier-Belleuse. This forms an exhibit, extraordinarily rich and well worth seeing, of modeled pieces in clay and wax and of water colors and drawings, which were made by this artist, that the products of the factory might be decorated with them. It is not difficult to find an unusual number of these practically carried out in the exhibition. One has great respect for such power and is brought at the sight of this work, involuntarily, to the conviction that here is a man who not only thoroughly understands the material which he uses as a ground for his artistic creations, but also that he possesses the power to bring lasting good to such an institution.

The second room contains the work of the technical school connected with this institution. The various pupils (their number is about twenty) show their ability partly in an exhibition of drawings and designs, and partly by work done upon the material itself for which they are receiving their education—that is, porcelain. This is also of great interest to us who are striving to develop the artistic power of our industries better than was formerly done. The school is young and therefore has not yet been able to furnish much aid to the private industries.

A third room contains the products of Sèvres of the present time. It consists, on one side, of a raised platform filled with articles made from the porcelain body used in previous years, and placed upon a table in two large cases reproductions of the pâte tendre body formerly used. On another side are articles from their new body which is called *porcelaine nouvelle*, then on another side, an old body. A number of large vases on pedestals are placed along the wall in the inner rooms. In the center of the room are the latest products, in a glass case that can be reached from all sides, which consist of pieces glazed in the *rouge flambé*, the cuprous oxide red.

The exhibition is very tastefully arranged and makes an imposing impression. It is justly the pride of the French. Technically the Sévres ware is especially noteworthy from the size of the pieces. In this direction a great deal has been accomplished in a manner peculiar to Sévres. Quite a number of the pieces shown are so large that they could not be thrown on the wheel. It was therefore interesting to know the method employed. These large pieces are made by a casting process for which purpose a special work room has been arranged at the factory. The body slip is in a large tank placed high enough to enable the largest mold to be filled from it. The slip passes through a wide pipe, provided with a cock and an air valve, beneath the floor of the working room to the middle of a large iron disk. This serves as a bottom for the molds which are cast of plaster in a special manner. By preventing any admission of air to the interior of the thick mass the molds can be kept filled until the piece, by absorption, has reached the necessary thickness. The mold is now covered and air is forced in by means of a pump. This forces the slip (still liquid) out of the bottom into the reservoir. After the mold has been emptied it must for some time be held under a strong air pressure, that is, about one-fourth atmosphere, as otherwise the body covering the sides would flow down to the bottom. This is accomplished by means of the same pump whose air pressure held the coating of slip firmly against the plaster mold and thus aided the absorption. The piece thus obtained when it is dry is always turned up on the outside and often on the inside in the air-dry condition. In this manner it is possible to make such large vases as, for example, the vase Cheret which was made in honor of the last transit of Venus and was about 2 meters high with a maximum diameter of from 1.3 to 1.5 meters. The vase body which is decorated in pâte sur pâte decoration is thus readily obtained in one piece, while the foot and neck are made separately and added afterwards.

A second notable thing technically is the "new porcelain" of Sévres. This consists of a newly prepared body which is much more fusible than the old, and in its composition is closely allied to the porcelain body of many Limoges factories, differing only in a noticeable percentage of titanic acid. That this is added as such cannot be assumed, as it comes more probably from the original body ingredients used. By reducing the burning temperature the factory has succeeded in producing a decorative technique, considered impossible hitherto. They are now in position to decorate this porcelain with thickly applied transparent enamels similar to the Chinese and Japanese enamels. These require, in order not to crack, a temperature corresponding to the melting-point of gold. The decoration of the pieces is, in the majority of cases, the same as in the case of the old body—colored glazes, underglaze colors, pâte sur pâte decoration in the most varied combinations, overglaze colors and, on the new porcelain, colored enamels. What makes the product so uncommonly charming is the artistic treatment. In the technical aids in decoration it is far behind the Berlin factory. The red obtained from cuprous oxide has generally a tendency towards blue, goes often to a bluish green, and is obtained in many shades, as is shown at the Sévres museum. Whether the pottery has brought the production of this color to a safe basis cannot be determined.

In addition to the large room with the later work of Sévres we find a salon with artificial light in which we see the effect of the light upon the products. A number of adjoining rooms show further the former work of Sévres, up to the exposition in 1878, under the empire, then to the year 1804, and finally the work of the last century. One obtains thus a comprehensive view of the work of this institution since its founding, and is enabled to follow the technical as well as the artistic advances.

Phenomena and Precautions in the Burning of Calcareous Clays

STANLEY G. BURT, TRANSLATOR

In a long article entitled "Phenomena and Precautions in Burning Calcareous Clays," in the *German Pottery and Brick Gazette*, Nos. 45, 47, 49, 51, and 52, of the year 1880, and Nos. 2, and 3, of 1881, W. Olschewsky presents some theoretical considerations on the processes occurring in burning brick-clays containing lime, and the colors which they impart to the clay. Mr. Olschewsky endeavors to show in these papers by proofs not remarkable for their accuracy, that the continuous kiln (to be sure, as it would seem only kilns built with the assistance of the technical bureau of the *German Pottery and Brick Gazette*) is the best burning apparatus for light-colored face-brick, especially those from calcareous clay, and that all contrary opinions upon this subject can be traced back to defective intelligence or to ill-will.

We could have left the reading of these interesting articles first to the readers of the *German Pottery and Brick Gazette*, especially since this work is not fully completed and there are probably at the close some more scientific surprises awaiting us, but for two characteristic points in them which compel us to take pen in hand for defense. These are the way in which the results of scientific research are twisted in the most arbitrary and forced manner to serve as a cover for business advertisements, and further the manner in which Mr. O. attempts to drag down those who have expressed an opinion contrary to his own, and he does this through personal attacks, casting suspicion on their scientific activity.

The writer of this considers himself so much the more justified in such a defense since he has the honor of being one of those personally attacked and who, some years ago, made investigations on the same subject—the coloring phenomena in burning clay containing lime—and proved the same by synthetical and analytical work. This work, which it cannot be denied could be carried on further, serves to-day as the foundation for the opinions generally held on this subject among the scientifically educated brickmakers and has been confirmed in practice. This work is not unknown to Mr. O. since he uses it most extensively when it serves his purpose; it should be presumed that he possesses the scientific education sufficient to enable him to follow the facts there laid down, and, should he not find them sufficient, to disprove them or enlarge them by exact experimenting. Instead of this he prefers, where previous work upon the same subject gives him no aid or more probably stands in his way, to prop up the dogma of the alone blessed continuous kiln by twisting these around in his own way or maintaining silence on the subject. In place of this he erects an airy building of hypotheses without deeming any experiments necessary, and with such a structure he flies in the face of well-known chemical and physical facts, in the wildest manner. This, however, with a circle of readers who, in the majority of cases, are not in position to go in detail to the bottom of these statements of Mr. O., may give the impression that one is dealing here with deep scientific research whose results, although somewhat reluctantly, must be taken as correct. There is nothing which can throw so much discredit on the aid which science can furnish to the practical worker as such hypothetical constructions which serve to support a business undertaking and to intoxicate, with apparently learned phrases, those for whom they are intended.

The position which the writer holds in regard to the continuous kiln is too well-known to render it necessary for him to define it more precisely. He was often charged with crediting this kiln, unequaled from the economical standpoint, with a higher position even for the burning of the better brick products than the majority of practical men would admit for it. The industry long ago formed its own opinion in regard to the value of the continuous kiln, and the articles of Mr. O. will have a hard time to shake it. It is true that an intelligent direction in the use of this kiln leads to much better results than those obtained in the great majority of cases, but it cannot be denied that a number of factors for the production of good face-brick are very unfavorable in the continuous kiln, and that in addition to an intelligent operation there must exist also special, favorable, local conditions in order to overcome the difficulties offered by the use of this kiln. This is attained in many places but where this is the case it certainly is not due to the theories sprung from the imagination of Mr. O. and realized in practical form. But let us see what proof Mr. O. brings into the field to support his statements, by making a brief analysis of his work.

Mr. O. commences by describing the character of the calcareous clays in regard to their composition. He describes them as mixtures of clay substance, quartz, and calcium carbonate, of which the latter often appears in larger grains and should then be separated out as a harmful ingredient, but when finely divided becomes harmless through its complete fusion with the silicates; indeed it is useful as a flux provided its percentage does not pass a certain limit. That in addition to the previously mentioned constituents of the clays, these contain feldspathic remains whose action in fusion should not be underestimated, can easily be seen from the analyses given, although no special mention of the same is made. At a low heat such clays (according to O. up to 700° C.) lose the chemically combined water, and at the same time the carbonic acid from the calcium carbonate; any organic matter is also burnt. A red color is now produced in the clay by the never-failing ferric oxide which (and this is characteristic) appears not only upon the surface but throughout the entire body.

At a higher temperature (according to O. at 800° C.) the clay loses its red color and becomes white or pale yellow, owing to the reduction of the ferric oxide. *This reduction is a fact.* Where did Mr. O. gain his knowledge of this fact which, it is certain, would be very convenient for his purpose? Certainly not from the investigations of others, and he fails to give his own because he might be told differently. He would have found in his experiments that silicates containing ferrous oxide are never white nor yellow but in the presence of a larger percentage of iron, as is without exception the case in the clays here under discussion (3 to 8 per cent and over), they are gray, black, dark green, or violet, according to the character and quantity of the other fluxes present, and the relation between the ferrous and the ferric oxide. This fact of the reduction of iron is shown according to O., by the production of the yellow color in the clay. He probably does not know that in glasses, which in their chemical constitution may be compared with a burnt brick, the ferric oxide belongs to the relatively weakest, the ferrous oxide and the intermediate oxides of iron to the relatively strongest coloring ingredients; and that the color, which ferric oxide dissolved in a silicate gives, varies according to the quantity between ivory-yellow and orange but is never red, which latter color is alone due to free iron oxide; further that the ferrous oxide glasses appear, even with a small per cent, dark green or black.

The iron calcium silicate, which has been formed at 800° C. with the reduction of the iron, is, according to O., a very unstable body which is easily decomposed. If the yellow color is to be retained (that is, the ferrous oxide, which never possesses this color), the bricks must be cooled slowly; if they are cooled rapidly, oxidation of the iron sets in and with it a red color appears. Has this conclusion, even were the premises correct, a logical basis? The chemist would have expected exactly the opposite, since in chemical reactions time is a factor, that is, the advance of a chemical reaction is proportional to the time during which it is carried on; one would have expected that in slower cooling (that is, longer action at a high temperature), the oxidation would have gone further. That one can, however, accelerate a reaction by shortening the time is a statement specially discovered for this demonstration which can not be made entirely plausible even to the lay mind. However, Mr. O. endeavors to explain this apparently paradoxical statement. The oxygen of the air, according to O., reacts more energetically at a lower temperature than at a higher, and since a rapidly cooling brick is under the influence of a cold stream of air and a slowly cooling brick is acted upon by hot air the action of the cold air is hence more energetic. What a child-like explanation! Have the devotees of science worked for tens and hundreds of years to establish the laws of nature to see here all their efforts come to naught before the wisdom of Mr. O.? Has any one ever seen that the burning coal is aided by cooling it and that it is put out by a higher heat?

The calcium iron silicate formed with a reduction of the ferric oxide at 800° C. has, however, according to O., a second enemy — the sulphurous acid in the fire-gases which comes from the fuel. Since the calcium oxide is a strong base it therefore enters only with difficulty (sic!) into the calcium iron combination. Should the calcium find a stronger acid (sulphuric acid) formed from the sulphurous acid and oxygen, it would be prevented from entering into the yellow calcium iron combination and the ferric oxide remains isolated and retains its red color. Since the red color is produced here by a gas the decomposition occurs only on the exposed surfaces while those not exposed remain white or yellow. The sulphuric acid formed at 800° C. is again driven off by increasing the temperature to 900°–950° C. The newly formed calcium iron silicate, also due to reduction, gains in stability, and discoloration is no longer to be feared.

Where does Mr. O. prove that at 800° C. sulphurous acid (and oxygen) acts upon the calcium iron silicate and that the sulphuric acid at the other temperature is again volatilized without ado with a simultaneous reduction of the ferric oxide? If Mr. O. had opened any technical text-book at the article "Sulphuric Acid," he would have found that upon conducting sulphurous acid and oxygen over large surfaces at a low red heat (for example, platinum, soft burnt clay, broken bricks) anhydrous sulphuric acid is formed and that this is a process which has been suggested for making sulphuric acid. That this is impracticable and that the method has only a historical value is immaterial. It shows that sulphuric acid is formed without the aid of calcium under the conditions existing in a brick kiln, that is, sulphurous acid, oxygen and glowing surfaces. The calcium oxide is, however, whether it be calcium oxide at a higher or calcium carbonate at a lower temperature, eager to take up the sulphuric acid contained in the fire-gases. He should have proved that the formation of sulphuric acid occurs exactly at 800° C., not at a lower temperature (for example, in the water-smoking fire); also that the sulphuric acid is again driven off at 900° to 950° C., and that the yellow color is again formed. If Mr. O. had remembered the well-known article by Pelouze, according to which glass made from sodium sulphate may contain a considerable quantity of sulphuric acid, or had found in a technical book that alkaline sulphates are not decomposed by silica at a much higher temperature than exists in brick kilns, except ground carbon be added, he would have had to consider the question whether this driving off of the sulphuric acid without its being reduced to the sulphurous acid in brick-burning occurred so easily and at comparatively so low a temperature. He states this, however, as if it were an indisputable fact, this being the easiest way. In a number of the *Notizblatt* (some years ago), Mr. O. will find an article by Schott, "On the Action of Sulphurous Acid upon Calcium," in which it is proved, by means of numerous analyses, that sulphurous acid, even without the presence of oxygen, is absorbed with great energy, forming calcium sulphate and calcium sulphide.

Further work on the rôle which sulphuric acid plays in burning clayware and which proves that, with coal-gas firing, and even in wood firing, the water which may be condensed from the waste gases is acid (owing to its content of sulphuric and hydrochloric acids), work done by myself, was published in the *Thonindustrie Zeitung* in the year 1878, No. 23, and has probably not remained unknown to Mr. O. That the source of the sulphuric acid is not in the zone of the kiln which is at 800° C., but in the water-smoking chamber and in the low fire, also that the sulphuric acid is not so easily driven off, is exactly the point upon which the difficulties of the use of the continuous kiln for burning light-colored face-brick from clays with or without lime rest. Mr. O. should have observed long ago in the use of continuous kilns, that the sulphuric acid which has reached the clay from the kiln gases and produced red spots upon the surface, by combining with calcium, cannot be driven off by merely increasing the temperature. If he had examined the fused and broken pieces from an old German kiln he would hardly ever have found these red spots but would have found them on fused and broken pieces of the same raw material burnt in a continuous kiln, and if he had not intentionally closed his eyes, seeking to deceive himself and others, he would have found the bricks from a German kiln to show an entirely different yellow color from those of a continuous kiln. According to O. the production of face-brick in a continuous kiln is very simple. He thinks he has shown that the bricks at 700° C. have a red color throughout, and that at 800° C. they are white or yellow, this color growing deeper with a higher temperature. The deep lemon-yellow color is the one most desired by architects. This is obtained at a temperature of 950° C. It is, therefore, only necessary for the intelligent brickmaker to obtain this temperature throughout his whole kiln.

The conditions, however, are not so simple, and a good bit of self-conceit would be necessary to accuse the practical man of lack of intelligence by such trivialities. If Mr. O. had cared to go deeper into the subject he would have found that burning clayware is accompanied by rather complicated processes, and had he gone deeper into these and explained them in a popular form it would have been of much more value to the readers of the *German Pottery and Brick Gazette* than his hypothetical structure. He could have explained to his readers that in addition to the clay remaining red through a soft fire, whereby the ferric oxide remains free and is not taken up by fusion, a second cause for the red color, which can and ordinarily does occur at the same time with the first and which takes place in the low fire and during the water-smoking, is a combination of the calcium on the surface with the sulphuric acid, thereby rendering the calcium inert as a flux and unable to draw the ferric oxide into combination. He could have made clear to his readers that in the processes at the higher temperatures the character of the flame is of special importance and that the fusion of the ferric oxide with the silicate, which is characterized by the appearance of the white or yellow color, is helped and in fact made possible when there is comparatively little calcium present. Owing to the fact that the ferric oxide is at times reduced to ferrous oxide, that this reduction does not occur voluntarily but can only be brought about under the action of reducing gases, that it oxidizes again just as soon as the flame is free from smoke (that is, becomes oxidizing), the color changes vary not between yellow and red, but always between gray or black and yellow as a final end-point. He might further have shown that the sulphuric acid taken up by the calcium from the fire-gases can be volatilized only by an intensely reducing (that is, smoky kiln) atmosphere at the temperatures here under discussion, just as in fusing glass an addition of ground coal is necessary even at a much higher temperature. He would have had to make clear, had he cared to let scientific accuracy prevail, that, not only according to the published researches of others but also according to his own, the kiln atmosphere in a continuous kiln is much more favorable to the production of the sulphuric acid in the preliminary firing than in the other old kilns, and that it is much more unfavorable for expelling it in the hard fire if the usual directions are followed and the stack is not allowed to smoke.

After his general theoretical consideration upon the processes occurring in burning brick kilns, Mr. O. goes on to a discussion of the differences in these processes when using a periodic or continuous kiln and he makes use of this sentence: "The opinion that the burning of face-brick is less difficult in the periodic kiln than in the continuous kiln is altogether wrong."

What does practice and the intelligent and scientifically educated brickmakers, of whom there are quite a number, say to this? Does Mr. O. expect to take the complaints so lightly which, since the invention of the continuous kiln, have been coming first to the Hoffman office and now to the technical office of the *German Pottery and Brick Gazette*? Does he always expect to correct the complaining parties with the charge of "lack of intelligence?" Where and when has the technical office, through its own intelligence, been able to overcome these difficulties so as to silence the complaints?

The burning process in a periodic kiln with grate-firing is now described. According to O., the wide variations in the composition of the kiln gases due to supplying fuel at long intervals is especially unfavorable since the current of air, which reaches the kiln contents when the fire has burnt down, must act especially strong (according to his theory) upon the decomposition of the calcium iron silicate and the production of the red color. Did Mr. O. ever discover in an old German kiln a red brick near the fire-holes where the cold oxygen should act with great intensity? Further, the periodical kiln is unfavorable with respect to color since the combustion is far from the distant parts of the kiln contents. Where has Mr. O. proved that having the fire close at hand is especially favorable for the product?

As proof for his statements in regard to the procedure in burning German kilns, Mr. O. cites an investigation which I published some years ago upon the process of burning in various kilns of the ceramic industry. He draws from this work the conclusion, as characteristic for the German kiln, that at each firing there is a marked change between reducing and oxidizing conditions which is coupled with a large loss of fuel. That reduction here is often carried too far can, according to O., be proved. How is this proof obtained?

From my investigations it can be seen that after a previous reduction there is always a shortage in the sum of carbon dioxide plus oxygen which theoretically should be close to 21 per cent. The oxygen lacking is used for reoxidizing the bricks; should this reoxidation not occur the bricks would leave the kiln gray in color. The balancing of the oxidation when carried too far occurs always in the cooling and is therefore unnecessary "since that which we previously reduced uselessly is again oxidized." If now under the influence of the last reducing fire the kiln is closed, and gradually through diffusion the kiln atmosphere becomes strongly oxidizing, the ferric oxide in the upper parts of the kiln separates out but does not do so in the lower; there is, therefore, a red color in the upper part but not in the lower, since the calcium iron silicate, owing to the higher temperature, has become inert to the action of oxygen. How far the deoxidation can be carried in order not to be useless Mr. O. forgets to say. He forgets to prove that the bricks in the upper part of the kiln ever were yellow and had become red through oxidation and he also forgets to show whether in the yellow bricks any constituents are present at all which can be oxidized. This proof would have been easy if he had been able or wished to furnish it.

According to Mr. O. the conditions in the continuous kiln are more favorable, in that the fireplaces (the fire-holes) are closer together and the fuel, owing to the flue projections, can be evenly distributed throughout the whole height of the kiln and, where necessary, the bottom of the firing shaft may be moved towards the crown by closing the heating flues either at half the height or still higher, an even division of the heat being thus obtained. To be sure, there is opposed to the uniform distribution of the heat in a horizontal direction, from heating flue to heating flue, the fact that the velocity of the flame in the continuous kiln is comparatively slow; this evil can be easily overcome by closer-setting, that is, by decreasing the open space in the kiln. The charge which is made against the continuous kiln that it gives less uniform burns than the periodic kiln is therefore without foundation, and it is possible to adjust the unequal distribution of heat in the continuous kiln, either by choosing a fuel having a long flame or by producing the same conditions in the continuous kiln by completely closing the damper that is obtained in the German kiln by luting it. Why it is that these conditions in the German kiln lead to an oxidation and to the red color it produces while it does not do so in the continuous kiln is difficult to understand; certainly Mr. O. owes us a proof of it.

Mr. O. obtains as his unprejudiced résumé the opinion that a continuous kiln fired direct is inferior to the periodic kiln in respect to an even burn only in so far that it is more difficult to handle and requires greater intelligence in its use. The necessity for greater intelligence or (as Mr. O. expresses it in another place) the practical experience together with not a small measure of scientific knowledge is more than paid for by the great economy in fuel. The practical man will not be able to solve the arithmetical problem of what value the economy in fuel will be to him when he must employ educated men, in fact persons with a university education, if the difficulties of correctly operating this kiln are so great. If the charge of an irregular temperature of the continuous kiln is thus set aside, the other conditions must be considered and it would seem, according to O., an unfavorable state of affairs that in the continuous kiln the bricks are cooled by direct admission of the air, that is, that they are subjected to an oxidation and the red coloration connected with it—an evil which is sought to be prevented most anxiously in the periodic kiln. In spite of this it is possible in the continuous kiln to overcome this difficulty.

According to O., the oxygen decomposes the calcium iron silicate of the brick only when the air which reaches it is cold, not, however, when it is hot and thereby expanded so that this decomposition is only possible when the air, which is in contact with the brick surface, is more than 50° C. cooler than the bricks are. Where does Mr. O. obtain these particular data? No one else has experimentally determined them for him and he does not say outright that he has done it himself. Has he proved at all that a yellow burnt brick can be changed by the action of the atmospheric oxygen? Those of its ingredients which are as yet known—silica, aluminum, iron oxide, calcium oxide and the alkalies—under these conditions are not changeable according to the opinions held by chemists up to this time; possibly Mr. O. has found other elements whose presence he ungenerously refuses to communicate to the scientific world.

In order to explain the remaining varying conditions in the operation of the continuous kiln Mr. O. is now compelled to take up a theme which, according to his ideas, cannot be done without becoming personal. The first victim of this theme is Mr. Stegmann who, in an article in the *Thonindustrie Zeitung* on "The Burning of Light-colored Face-brick, Terra Cotta, etc., in Gas-fired Kilns," expressed the heretical conclusion that highly calcareous clays which burn to a yellow color must be fired under varying oxidizing and reducing conditions in order to result in a good clear color. I can best leave to Mr. Stegmann the discussion of this personal attack. As far as the facts go, I share these opinions of the laiety as Mr. O. likes to call them; in fact, I have a strong presentiment that Mr. Stegmann has gained his conclusion from my investigations published upon the action of kiln gases on clay. I must therefore acknowledge that I share these opinions of the laiety, however much they are opposed to the dogma all powerful in Kessel Street.

Mr. O. is right only in the fact that an alternating, reducing, and oxidizing condition is connected with a waste of fuel compared with constant neutral conditions (which point no one has ever contested up to this time). But his taking, as an example, the conditions prevailing in boiler-firing is very lame since no one has ever undertaken or ever desired to burn yellow face-brick under a boiler. According to Mr. O.'s opinion, the alternating, reducing, and oxidizing character of the flame so indispensable in obtaining clear colors in the periodic kiln is not necessary in the continuous kiln, since by using suitable rules in setting and firing we can modify the too strongly oxidizing action of the gases in it so decidedly that the carbon dioxide rises from 12 to 17 per cent. This would correspond to from 4 to 9 per cent of oxygen. If this percentage of oxygen no longer has an oxidizing action but is actually reducing in character with respect to the sulphuric acid which has caused the red spots in the preliminary fire Mr. O. should have proved this by indisputable experiments; but so long as he has not done this his conclusions remain a phrase without meaning. He grants further on that it is certainly difficult, on account of the lack of intelligence of the burners, to obtain such a uniform composition of the gases. In firing the continuous kiln with gas there is no such difficulty, as here it is possible to maintain a uniform composition of the gases of from 16 to 20 per cent of carbon dioxide, that is, 1 to 5 per cent of oxygen. Does Mr. O. expect by such unproved statements to make us believe that with the use of gas all difficulties in the continuous kiln are overcome? The inventor of the gas-fired continuous kiln would hardly give him thanks for this unscientific assistance.

The second person who raises the wrath of Mr. O. by heretical statements in regard to the continuous kiln is myself. Mr. O., although he has drawn much of value concerning the periodic kiln from my work, remarks in the following manner upon the wrong conclusions from it on this same subject:

"Seger has aided in spreading another error about the continuous kiln in that in his article entitled 'Studies upon the Composition and Action of Kiln Gases in the Ceramic Industry,' a number of gas analyses are given from which it would appear at least *to the laiety* that the character of the kiln gases in the end of the continuous kiln tunnel being fired is exceedingly varied and that for this reason it is impossible to obtain a uniform color upon the ware.

"I say distinctly that this work must produce with the laiety the impression that the continuous kiln is a very impracticable apparatus for this purpose. Every one who knows from practice what great influence in the continuous kiln the manner of the setting (the different spacing between the bricks at varying heights of the kiln) and the intensity of the draft exerts upon the movement of the air, the fire-gases, and on the water-smoking, will agree with me in this respect, that a scientific series of experiments with the continuous kiln should be considered worthless, unless the conditions are so completely analyzed that one can weigh all the important factors, which are of influence upon the results of the experiments. This is by no means the case in Seger's work and it is, therefore, as has been said, valueless from a scientific point of view since in another kiln, in which the bricks are set wider at the bottom and closer at the top and in which care was taken to obtain combustion of the fuel at the top as well, one might prove the opposite of Seger's conclusions. For the practical man, who is not always able to test carefully the reasoning of a scientific series of experiments and who, therefore, accepts the result as correct without further consideration, the work of Seger may be a direct danger, since it does not show that a great many factors in the operation of the continuous kiln are of great influence upon the composition of the kiln gases found in different parts, and furthermore, since one is led to take the results of Seger's work as the standard for a well-conducted continuous kiln.

"I shall not cite any special experiments to define the conditions necessary for obtaining good results in regard to uniform color, in a well conducted continuous kiln, or to determine a common standard for burning clays containing lime, but will confine myself to giving the conclusions of my numerous investigations on the continuous kiln which I have carried out, not one-sidedly (only with the aid of the Orsat apparatus) but with the assistance of a draft gauge, an anemometer, and a pyrometer, and under varying conditions which, owing to their very diversity, often produced only for the purpose of study, have given me the right to criticize the work of Seger as I have done."

It does not seem to me fair that Mr. O. keeps his work, from which he has learned so much, from criticism by remaining silent about it, while others, and with them myself, have given theirs for his approval and must patiently allow it to be disprovde. I find it, however, even less fair when he puts conclusions into my work, which no one would find there unless very anxious to do so. With me it is no object to make propaganda for or against the continuous kiln and to adjust my investigations to this end; on the contrary, I seek to gain a comprehensive view of the burning, in the various kilns used in ceramics. That the investigations can be carried further in many directions goes without saying. I have observed the kilns as they were fired under ordinary working conditions. If during the firing I varied the ordinary method, it was done in order to prove that the same conditions could be produced in the continuous kilns, which were leading to good results in the old German kiln next to it. If Mr. O. has not learned more from my work than this, I am sorry for him. Without making any unjustified advertisement for the continuous kiln which I am in no way bound to do, I think I have given some valuable points to Mr. O. If he has not used these it is his fault; I meant well and he should therefore pardon me.

After this digression into the field of personal polemics, Mr. O. returns to his proof and feels himself led "to set right and to standardize" the extremely varied opinions which are held in regard to the path which the gases take in the continuous kiln.

He does this with a schematic drawing of the longitudinal section of a lengthened continuous kiln in which those portions of the kiln, where any movement of the air takes place, are shown by shading which, in the region of the full fire, fills the whole kiln, but towards the cooling and the preheating end of the kiln becomes narrower. How far this graphic representation of the air movement is due to direct observations and how far to conjecture cannot be estimated, since Mr. O. furnishes no proof of it. So much, however, can be concluded, that the reasoning is based upon a very weak foundation, since one important factor in the movement of air, which might alter the conclusions considerably, is left out of consideration altogether. Mr. O. "standardizes" the movement of the air in the following manner:

The cold air entering the kiln moves first along the floor; as it is heated it rises, owing to expansion, until, near the full fire, it fills the entire kiln. In the full fire further expansion is not possible, therefore pressure is caused. This pressure decreases in the cooling parts of the kiln. The moving gases can no longer fill the entire kiln; the contraction is partly hindered by the water vapor which the clay gives off. It goes without saying that the gases now move beneath the crown and that at the bottom of the kiln a space is left (corresponding to the contraction) in which no movement takes place. The character of the forward movement of the air remains, under varying conditions, about the same, the conditions varying only, as the curves show, with a stronger or weaker draft, and with wider or narrower setting.

That a pressure can be maintained permanently in one part of a free kiln space produced by local expansion of the air is, at any rate, a great enrichment of science. In order to make this worthy of belief a proof might have been desired. That a certain tension can be noticed under the crown in the back part of the kiln is, of course, a well-known fact. Mr. O. should have proved that this is greater than the force acting on the gas, considering the height of the kiln less the suction from the stack, and allow for the friction which diminishes the kiln draft.

Mr. O. assumes that the movement of the air is uniform; in order to hold in the kiln the quantity of air expanded by heating, he is compelled to assume this pressure. There was, however, a way out of this dilemma if he had allowed the air, with increasing temperature, a greater rapidity of movement. If he had now sought for a scientific support of this statement he could easily have found it in every physical text-book, where it is said that gaseous bodies under the influence of an impulse show the greater a velocity the lower their vapor density; he would also have found there the mathematical expression of this law.

However, one of the factors which hinders the standardizing of the air movement in the continuous kiln, consists in the settling of the ware and in the resultant space beneath the crown. Mr. O. easily gets around this by advising that the clay be supplied with suitable non-plastic material, so that the contraction may be reduced to a minimum; in addition, this condition can be met by the correct setting of the bricks. Does every paving- and face-brick manufacturer possess this necessary non-plastic material? This will probably not always be the case, and he will be compelled to make use of a kiln system in which shrinkage is less disturbing than in the continuous kiln. From his statements, Mr. O. draws the following résumé:

"*If we will use the aids just mentioned in burning calcareous clays in a continuous kiln, it will be possible even in burning paving-brick and much more easily in burning face-brick, which, since they are not perfectly vitrified, shrink but little, to obtain a uniform composition of the kiln gases throughout the whole kiln. That the chemical character of the air and the fire-gases in the portions of the kiln tunnel being fired is a varying one, must be considered a matter of course, so that experiments to determine this are entirely unnecessary. However, only ignorance or superficial judgment could ever find in this fact a drawback for the firing of the continuous kiln, since the property which is so characteristic, so peculiarly valuable in continuous kiln-firing, from which grows its great value for burning light-colored face-bricks from calcareous material, is just this constant increase of* *carbon dioxide in the waste gases, and the possibility resulting from this to heat the ware in an atmosphere, which need never be so oxidizing in character as to produce the undesirable red color.*"

Sapienti sat. It seems to me that Mr. O. would have done better to have given less play to his imagination and exerted himself more in going to the foundation of the actual facts. If we desire to support a proposition by scientific investigation we must first of all be careful to test the facts given from an unprejudiced standpoint and from these, whether they be our own or come from others, we must only draw such conclusions as the facts justify. To endeavor to prove a fixed dogma by forcing the facts, aids neither science nor those whom one seeks to instruct; on the contrary, only harm is worked thereby in furnishing to the unscientific man discourses upon processes which are beyond his understanding and which upon investigation prove to be unfounded.

Criticism of another's views, observations and discoveries is not difficult provided one has sufficient self-esteem and a facile pen, but such criticism in the field of scientific research is right only when it is accompanied by reliable proofs.

Open Letter to Dr. Seger

STANLEY G. BURT, TRANSLATOR

Your defense which appeared in Nos. 5 and 6 of the *Thonindustrie Zeitung* replying to my article on "Phenomena and Precautions in the Burning of Calcareous Clays" compels me to a reply, which I will give the form of an open letter. It is not the partly open, partly hidden, attacks of my views and my person which have caused me to write these lines but, on the one hand, the method of your defense and, on the other hand, its incompleteness. This result was inevitable since, owing to causes which were at once clear to me, you published your defense before the conclusion of my article had been printed in the *Deutsche Töpfer und Ziegler Zeitung*. In consequence of the rapidity with which you wrote your defense, it contains certain sentences which, with more leisure, you would probably have omitted but since they have been published they compel me to a reply because they not only touch me but others as well.

You charge my work with serving as a business advertisement. To this I will only answer that the foundations for the opinion which I hold to-day, as a full conviction, were laid in my former position with an opponent of Hoffman, with whom I was occupied in making a careful investigation of the continuous kiln. My favorable judgment I obtained from the opposite side and my later position with Hoffman, in which I had and still have the opportunity to study the operation of kilns producing high-grade products, has in no way weakened the favorable opinion formed by me some time ago. Further I do not consider that the dependent position of an employee has a moral influence to the degree which you hold, in placing at the head of the paper established by you, the following words: "We think we are only able to do good work when we are free from every moral as well as material influence, etc."

As to the method at the bottom of your defense the reader must gain an opinion of my work from the sentences taken from it, generally without any connection, like one who, with the aid of analysis, endeavors to form an opinion of the character of a mineral by studying its separate ingredients. This quoting of separate sentences from my work especially when done from a prejudiced standpoint must necessarily lead to false conclusions. Whoever has read my work in its whole and with care, will find that I have endeavored to describe to the reader a method of operating the continuous kiln which would allow, even with direct firing, the production of pure colored brick from calcareous material. What you consider imagination on my part, however undesirable this may be for your theory, according to which light-colored face-brick can only be burnt under alternating reducing and oxidizing conditions, has become through practice an indisputable truth. For example in B. (the completed name you will know), perfect buff bricks are burnt from a calcareous clay, also known to you, with fuel containing sulphur (lignite) and burned without the aid of reduction. Although the bricks burned at B. so far, are not entirely satisfactory in regard to a perfect, uniform yellow color, still red bricks, on the whole, are a rarity although there is no alternating reduction and oxidation. In my work I have endeavored to describe the operation of the kiln to the practical man so that he might be in position to produce like results with his kiln, and I have started from the axiom that, with the same kiln, the same fuel, and the same conditions, like results ought to be obtained. At any rate the majority of readers of my article who are struggling with red discolorations will be placed in position by following the methods I have described, to operate their kilns successfully without extra cost; time will show whether my views on the burning of calcareous material are well founded or whether an unknown power in B. is assisting in the burning of buff bricks from calcareous material.

Now as far as the theory goes, which I have formed to explain, why it is possible to burn in the continuous kiln (without alternating the reducing and oxidizing gases) buff bricks from calcareous clay without any red coloration, it is in no way overthrown by the argument contained in your defense, dictated, as it is, from a prejudiced standpoint, according to which all red colorations are only the result of the action of sulphuric acid. It must be left to further scientific work and to the unprejudiced observations made in practice to furnish material sufficient to enable us to found a firm theory and leave hypotheses behind us. In the exceedingly varied constitution of silicates and the exceedingly varied action of almost identical silicates, there still remains a very wide field for hypothesis. What led me to assume the ready decomposition of the iron silicate formed at about 800°, was the discovery made at B., that red coloration would certainly result when the cooling chambers approached too closely to the firing-holes. The same thing was observed when in places which, on account of leakage, enabled cold air to enter during and after the firing, red discolored bricks resulted, while the neighboring bricks not reached by cold air were yellow in color. By maintaining conditions of slower cooling and with kiln gases of neutral or at least no longer strongly oxidizing character it was later possible at B. to burn, continually, perfectly pure, buff-colored bricks without any reducing action, and I have endeavored to explain in my work the conditions which were necessary to accomplish this. To this, important observations from practical experience are joined which are strongly supported by the experiments you carried out with the old German kiln with the conclusions drawn from them by me, so that the explanation which I seek to give of the phenomena in burning calcareous clays, supported by the valuable practical result at B., is by no means overthrown by the argument in your defense which stands in part upon a pretty weak foundation.

The form which your defense has taken will appear original to many of your readers who are not in position to determine the truth in what you offer. How far your defense goes in this direction I will show by a single example. You write: "The oxygen of the air, according to O., works more energetically at a lower temperature than at a higher, and since a rapidly cooling brick is under the influence of a cold stream of air and a slowly cooling brick under that of a hot one, the action of the cold air is hence more energetic. What a masterly explanation! Have the devotees of science worked for tens and hundreds of years to establish the laws of nature to see here all their efforts come to naught before the wisdom of Mr. O.? Has any one ever seen that the burning of coal is assisted by cooling it and is quenched by a higher heat?"

I can easily answer your question by saying that it has been customary to aid the burning of coal (of course, in the glowing condition in which the necessary heat is present to produce affinity) by cooling, since the time that man learned, by blowing up glowing sparks, to kindle them to a flame and on the other hand to use the same means to cool soup which is too hot. But putting joking aside I give you a few questions to answer upon facts well known to those dealing with pyrotechnics.

1. A burning light is extinguished more quickly under a glass bell, the air in which has been exhausted by the pistons of an air-pump, although the gas which remains in the bell has a higher percentage of oxygen than when the air, under like conditions, is not expanded.

2. By heating air it undergoes strong expansion.

3. In locomotive-firing, very rapid combustion is obtained with a small grate surface by using a very strong draft, the cooling action of which cannot be questioned.

4. Fire which is supplied with hot, not compressed, air consumes less fuel with the same velocity of the gases, that is, combustion is less active than when furnished with cold air. On this account the ratio of the combustion space to the kiln volume in the continuous kiln which uses preheated air is much greater than in the old German kiln which supports combustion with cold air.

5. In blast-furnaces the observation has been made in using a preheated blast (300° to 400°), that the effect obtained by its use is much greater than that calculated, allowing for the heat contained in the preheated blast. The explanation was given by many keen investigators that the hot blast does not burn the coal in the blast-furnace as the cold air to carbon dioxide, but only to carbon monoxide which exerts a reducing action upon the iron oxide in the regions above it, thus aiding notably in the production of iron (this is a decrease of chemical affinity by an increase in heat).

6. At certain temperatures which Deville gives for water at about 1000°, for carbon dioxide at 1100° to 1200°, the chemical affinity is so weakened that the well-known phenomena of dissociation appear.

I will leave it to you to inform yourself on this subject and to give more careful thought to your reply and to a number of other things contained in your defense (*Deutsche Töpfer und Ziegler Zeitung*). W. OLSCHEWSKY.

BERLIN, February 10, 1881.

Open Reply to the Public Letter of W. Olschewsky

STANLEY G. BURT, TRANSLATOR

You honored me in No. 10 of the *Deutsche Töpfer und Ziegler Zeitung* with a public letter and it would be inconsiderate on my part not to reply to it. My defense against your article "Phenomena and Precautions in the Burning of Calcareous Clays," and the attacks which it contained against me, I am sorry to find has not met with your approval either in form or contents. I at once agree with you in one respect. The form did not please me either, still I trust you will pardon me since at that time I was overburdened with work. I promise you, so far as it is possible, to improve my style. When, however, you discover a deeper cause for the rapidity of my defense, which did not await the conclusion of your article, but do not explain it, I cannot understand what else you could have found than the prompt and justified denial of an unreasonable attack. Your person is in this case entirely irrelevant; this denial would have been given any third person with the same precision.

You charge me with accusing you of making an unjustified advertisement. I certainly did this. Your article made this impression upon me as it did upon many others. You see (and to my sorrow I had to experience this from you) that a writer cannot be careful enough in the choice of his words; it is easy to be misunderstood.

You consider the position of a private official not necessarily a prejudiced one. I agree with you. In my opinion one employee may be quite independent while others may be strongly influenced, according to their position and personality. I asked you for an explanation of many interesting points. Permit me that I repeat these to you again in a brief and precise manner, since in your public letter no attention was paid to them.

1. How have you proved that at 800° C. calcareous clays undergo a color change from red to yellow, with a *simultaneous reduction of the ferric oxide*, while the surrounding atmosphere not only is not reducing but contains free oxygen? What be-

comes of the oxygen from the ferric oxide? Does it become free oxygen?

2. How have you proved that the yellow color is not due to the ferric oxide but to a lower oxide?

3. How can it be explained that iron oxide is separated out from a ferric silicate, *by a stream of air*, as free red ferric oxide? What is the chemical reaction here?

4. Why does a stream of air have a more energetic reaction when it is cold than when it is hot, contrary to the generally accepted opinion? Can you prove experimentally that a difference in temperature of at least 50° C. between the bricks and the air is necessary in order to produce the above-mentioned effect, or where have you proved it?

5. Why does this decomposition by a cold stream of air no longer occur at 900°, but only at 800° and below? You call the compound "fixed." What do you understand by this?

6. How do you prove that an absorption of sulphur compounds by the calcium occurs exactly at 800° C. and only in presence of an excess of oxygen, not, however, at lower temperatures with but little oxygen?

7. By what experiments have you proved that at temperatures from 900° to 950° the calcium sulphate is decomposed by the silicate without the aid of any reducing agent?

8. Why do you cite dissociation phenomena to explain reactions at 800° to 950° when you yourself give the beginning of dissociation at 1000° or 1100° to 1200°? Have you shown experimentally dissociation phenomena at 800° to 900° C., that is, much below the minimum assumed up to this time?

Instead of answering these and other questions you treat me, in your public letter, somewhat shabbily by citing from your practice only one case in which your hypothesis seems to be splendidly proved. I expected a very considerable number of names of brickyards in which you had succeeded in burning light-colored face-bricks from calcareous clay with fuel containing sulphur, in a continuous kiln with an oxidizing flame. And now you appear with a single kiln at B., and even here you are compelled to add that the color, upon which the discussion hinges, is not entirely satisfactory. But why do you not give in full the name of B., why do you maintain silence before your readers, so anxious for knowledge, and why are you so diffident? From your explanation in the *Deutsche Töpfer und Ziegler Zeitung* there can be meant but two names by B., since these are mentioned in full by you in another place; these are Bellin, near Ueckermünde, and Birkenwerder, near Berlin. But when one comes to think about it these brickyards cannot be meant, the first certainly not, since it, as far as I know, does not produce face-brick on a large scale, and it cannot be the second because there gaseous fuel is used. This is provoking, since the whole discussion centers on the burning of face-brick in the common, continuous kiln, fired direct. However, let us assume that B. is Birkenwerder and we will not consider the gas-firing. You say that there the flame is either neutral or at least has not a strongly oxidizing character. You give the carbon dioxide contained in it at from 18 to 20 per cent; the real measure of the oxidizing action, the percentage of oxygen, is not given, but we can assume from your article that it is probably but small. Are you certain that during the twenty-four hours, owing to wind, change of weather, and irregularities in the generators, not once, twice or even three times for fifteen minutes at a time this boundary, which you expect to follow so sharply (which is characterized by the complete absence of oxygen), has not been passed? I think this is very doubtful, in fact I am somewhat doubtful on the reliability of your figures. One cannot be too strict in establishing figures for a proof since they are of such exceeding importance in scientific research. As errors will occur and are pardonable, we must at least have a guarantee that above all else they are *bona fide*. At the last convention of the Brickmakers' Association you appeared in rather a peculiar light in this respect which, however, you will probably be able to explain and will certainly not find it difficult to clear yourself; until then, however, you must pardon me if I am somewhat skeptical. Think of the harm resulting to practice by incorrect scientific figures. Many, through blind faith in the infallibility of science have lost house and home; hence, the practical man cannot be blamed for his distrust. One should always consider his scientific responsibility!

Except for your example cited from practice you answer in your public letter but one question, why it is that a glowing spark is raised to a flame by a cold stream of air. Your comparison with the hot soup I will pass over as poor taste; it needs salt. Well, a spark then is kindled by a cold stream of air; this is an undeniable fact and easily proved. According to your idea the stream of air acts with a special energy when it is cold. Did you ever prove to yourself that a hot stream of air would not probably have a more energetic action? Theory and practice would have expected this. But no, you can use for your purpose only a cold stream of air. Up to this time it has always been believed that a cold stream of air was active because it carried the oxygen necessary for the combustion and that this action of the oxygen was not on account of, but in spite of, its being cold. However, one can have his own special ideas about the most elementary facts.

You turn my attention to a number of phenomena which should go to explain the above fact in your way and which you group under six heads. Since by chance I have been much occupied upon exactly these things I shall be glad to reply to your questions.

1. "A burning light is extinguished more quickly under a glass bell, the air in which has been exhausted by the pistons of an air-pump, although the gas which remains in the bell has a higher percentage of oxygen than when the air, under like conditions, is not expanded."

Well, this question does not seem so difficult. Oxygen, like every other body, combines with greater difficulty the more diluted it is, and a light goes out under a glass bell before all the oxygen has been consumed just as soon as the decreasing evolution of heat becomes smaller than the heat lost. If one brings about this dilution by exhausting the air, the light is extinguished so much the sooner. Consider, however, the combustion in a bell heated up to 800° or 950° C. (you refer to the continuous kiln and this certainly would not be too high a temperature). Here you would find no oxygen when the flame is extinguished. Hence do not apply phenomena to conditions into which they do not fit and only draw those conclusions which are justified from the premises.

2. "By heating air it undergoes strong expansion."

I never doubted this to any extent. I remember very well the first experiment in physics which I carried out as a boy; it was upon this point exactly. I was playing with a glass in a wash-basin, and observed that by inverting it and dipping it in the water, the water not only did not enter it but when I had held it for some time in my hand air was released. I pride myself a great deal even to-day on the fact that I, although a boy, was able to find the correct explanation.

3. "In locomotive-firing, a very rapid combustion is obtained with a small grate surface, by using a very strong draft, the cooling action of which cannot be questioned."

We demand from a locomotive boiler an enormous production of steam in a short time. This steam requires for its formation one-seventh to one-ninth of its weight in coal on the average. The coal which for simplicity's sake we consider as pure carbon requires for each 6 parts, 16 parts of oxygen. Since 1 cubic meter of air, of mean pressure and at 0°, contains only 299 grams of oxygen (and these are only able to burn about 112 grams of carbon), it is necessary to provide an immense quantity of air in order to develop so much steam. Since the cross-section of this stream of air is small it must have a very high velocity. It is not active because it is cold but in spite of it, since it brings in a great quantity of oxygen. However, when preheated, its action is more energetic, provided the velocity has increased in proportion to the expansion. Volumes of gas can be compared only at the same temperature and pressure. A spark is thus kindled by a cold stream of air because the latter contains oxygen and not because it is cold; it would have been kindled much better by a stream of hot air and would not have been, as you seem to think, extinguished.

4. "Fire which is supplied with hot, not compressed, air consumes less fuel with the same velocity of the gases, *i. e.*, com-

bustion is less active than when furnished with cold air. On this account the ratio of the combustion space to the kiln volume in the continuous kiln which uses preheated air is much greater than in the old German kiln which supports combustion with cold air."

This seems to me pretty self-evident. A smaller quantity by weight of air will pass through the same room if it is of a higher temperature, under your condition of equal rapidity. This can, of course, consume only a smaller quantity of coal; if it is desired to make a comparison, one must compare equal weights or unequal volumes reduced to the corresponding temperature and pressure conditions. The amount of air which enters the kiln is governed by the amount which passes out of it and the pressure and velocity always adjust themselves so that the space remains filled. That, however, the combustion in the continuous kiln with hot air is less energetic than in an old German kiln with cold air is a fact which I do not dare to contest. However, it may have a different reason and perhaps I may be able to direct you to the right explanation. Is it not possible that in the continuous kiln the oxygen goes its way partly without bothering about the coal, while on a grate fire (whether cold or hot, provided that only the coal is hot) it is compelled to come in close contact with the carbon? Besides, let me say that other authorities have held exactly the opposite view from that which you place in your premise. These, however, have certainly made an error in assuming, except for the different temperature of the air supplied, otherwise equal conditions.

5. "In blast-furnaces the observation has been made in using a preheated blast (300° to 400°), that the effect obtained by its use is much greater than that calculated, allowing for the heat contained in the preheated blast. The explanation was given by many keen investigators that the hot blast does not burn the coal in the blast-furnace as the cold air to carbon dioxide but only to carbon monoxide which exerts a reducing action upon the iron oxide in the regions above it, thus aiding notably in the production of iron (this is a decrease of chemical affinity by an increase in heat)."

It seems to me that some factor has been left out of consideration in the calculation which ought to be taken into account so as to bring the theoretical debit to correspond with the practical credit. In the second point you seem to be in error. As far as I know the iron industry, I have always believed that the whole process of the blast-furnace was based upon the production of carbon monoxide in the hearth. As far as I know, no iron has ever been reduced by carbon dioxide. The only thing I am amazed at in your explanation is its logic. The production of iron increases with heat, and the production of heat with the energy of the chemical processes; therefore, with a higher production of iron, the chemical action must have been less energetic. Is this not absurd? It seems so. You will probably remember that the temperature in front of the tuyeres of the blast-furnace, even with cold air, is estimated as being above the melting-point of platinum. Is it not possible here that even with the cold blast dissociation phenomena occur? Think about this a little.

6. "At certain temperatures which Deville gives for water at about 1000°, for carbon dioxide at 1100° to 1200°, the chemical affinity is so weakened that the well-known phenomena of dissociation appears."

This is a very interesting theme, and upon your advice I was led to study the works of Deville and Troost a long time ago. I understood from it (perhaps I am mistaken) that the energy of the oxygen increased up to this limit, so that the highest oxygen compounds, water and carbonic acid, result. However, on further heating, some free hydrogen or carbon monoxide can exist together with free oxygen in the flame, without undergoing combination. Again, the percentage of substances which cannot unite is the greater the higher the temperature. Thus an infinite increase in temperature by combustion cannot take place. The point of complete dissociation lies far above the fusing-point of platinum, since it is possible to fuse platinum, though difficultly, with coal and a stream of cold air, but more easily with a hot-air blast. It is somewhat difficult to understand these conditions; perhaps you will, on serious study. Nevertheless, that you involve dissociation for the continuous kiln surprises me. You claim to have proved yourself that the temperatures in the burning of calcareous clays lie between 800° and 950°. This is far below the minimum point of dissociation but within the limits in which the activity of oxygen increases. My main interest in this point is a psychological one, to observe what things one can deduce by logic from a fixed idea.

I have answered your questions as well as I am able, and now will you have the goodness to answer mine, as you know I am very eager for information? But in conclusion one thing more, let me ask you that your premises be based upon indisputable facts and the conclusions drawn from these premises be logically thought out and convincing. I shall be thankful to you for this and you may be sure that I will be the first to greet you most friendly, with "Soyons amis, Cinna!"

DR. H. SEGER.

The Hainstaedt Clays

STANLEY G. BURT, TRANSLATOR

Some time ago Dr. Strohecker, of Frankfort, in the *Technical Notes for Painting*, 1886, No. 17–18, published an article on the clays from Hainstaedt, near Hanau, in which he endeavored to prove that this clay contained a high percentage of rare earths which are very closely allied to aluminum. He claims to have found there beryllium, yttrium, and especially cerium oxide, together with lanthanum and didymium which are always found with it.

However improbable this appears, still such an occurrence is not an impossibility, and the article created on this account special interest in chemical circles. But it was also of interest to those interested in the clay industries, since the writer attributed the buff to brown color of the well-known Hainstaedt face-bricks to the presence of cerium oxide. It is true that there would have been found here an ample source for the otherwise so rare metallic oxides which are only found in small quantities. This would have permitted a commercial development and the application of these oxides for many purposes, as, for example, the yellowish red and violet-red colors for the clay industry. In this way these most rare materials, rarely seen by the chemist, would have been obtained by the wagon load.

At the time the work appeared, we made a short report of it in this journal. In No. 9 of the *Journal für praktische Chemie*, the Swedish chemist, Prof. Blomstrand, in Lund, who is an authority, especially on the subject of cerium oxide since he has himself added much to our knowledge of it, picks Dr. S's article to pieces. He not only shows that the Hainstaedt clay, which he obtained, did not contain any of the rare oxides, but that Dr. S. has attributed to them certain properties which they are not found to possess. Professor Schertel, who made a report on this subject to the German Chemical Society, reached the same conclusions as Blomstrand, and Dr. Bischof also was not able to find the didymium oxide which shows up well in spectrum analysis. I would have considered the matter as settled had not Dr. S., in a second article in the *Technical Notes for Painting*, adhered to his opinion. He endeavors to explain the fact that Blomstrand and Schertel could not find the rare metallic oxides since all Hainstaedt clays do not contain cerium but only certain strata of it. The above investigators probably did not examine the proper strata. He has undertaken the entire production of the cerium compounds, and they are only to be obtained through him.

I applied to Mr. S. and from him, on payment, I obtained these raw materials, supposed to contain cerium, and hence I was in position to possess genuine samples for examination. These are, according to his statements, the clays No. I and No. II*a* as he investigated them. I also obtained from Mr. S. a quantity of cerium oxide which, according to him, contains about 10 per cent of ferric oxide. There is, therefore, no possibility of doubt concerning the materials investigated. Now what does the clay and the so-called cerium oxide contain?[1]

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[1] Mr. S. gives as his analysis in No. 17 of the *Technical Notes for Painting:*

The results of my examinations are as follows:

	No. I.	No. II*a*.	So-called cerium oxide.
Silica, - - -	54.46	70.36	4.36
Titanic acid, - -	0.26	0.16	——
Alumina, - - -	29.00	17.50	trace
Ferric oxide, - -	3.59	1.69	59.54
Calcium oxide, - -	0.33	0.72	3.21
Alkalies (calculated as potassium oxide), - -	3.66	1.27	1.88
Water and organic matter, -	8.95	8.63	Loss on ignition. 30.73
	100.25	100.17	99.72

Of the substances found by Mr. S. in his analysis, beryllium, yttrium, the oxides of cerium, lanthanum, and didymium, no trace could be found with the characteristic tests for these.

The investigation was made according to the method ordinarily employed in analyzing such silicates, special attention being given to the rare metal oxides. To go into the details of the methods employed by Dr. S. I have no desire, since these are entirely unsuitable. It is only with such methods and

	No. I.	No. II*a*.
Silica, - - - -	47.5444	58.3331
Titanic acid, - - -	trace	......
Alumina, - - -	24.5937	11.7607
Beryllium oxide, - - -	6.4399	5.3833
Ferric oxide, - - -	0.9190	0.6356
Cerium hydroxide, - -	13.4214	9.4012
Didymium oxide, - -	......	0.8474
Lanthanum oxide, - -	0.8576	2.6536
Yttrium oxide, - -	......	1.6949
Magnesium oxide, - -	1.5901	1.8656
Calcium oxide, - -	......	0.5883
Calcium sulphate, - -	0.1361	0.2015
Calcium carbonate, - -	0.8878	......
Phosphoric acid, - - -	trace	2.0691
Potassium oxide, - -	2.3236	0.5648
Sodium oxide, - - -	1.2137	0.5838
Ammonium chloride, -	......	0.0529
Loss on ignition, - - -	......	4.1059
	99.9273	100.7418

The exactness with which Mr. S. has worked is amazing. To determine the ingredients found accurately to the fourth decimal place is an accomplishment other chemists would not have been able to do.

with an imagination of little use in scientific work that these rare metal oxides could be found. I would do the work of Mr. S. too much honor to attempt to disprove his erroneous conceptions in detail.

There can be no doubt that the color of the Hainstaedt clay in burning is due to its content of ferric oxide and alumina, as we have always found it in other clays having the same burning color, and as far as the influence of cerium oxide upon the color goes or the commercial production of the latter which Dr. S. has in mind, it is out of the question.

PROF. DR. H. SEGER.

BERLIN, August 15, 1886.

Reply Referring to the Hainstaedt Cerium Clay

In No. 34 of the *Thonindustrie Zeitung*, Prof. H. Seger says that he cannot find the rare earths in clays No. I and No. II*a*. Still he acknowledges that his investigations were carried out by the ordinary method of analyzing silicates.

I must acknowledge myself that I was not able to find cerium in this way but only after testing for it in a special manner, which I have described, and which, I repeat, is not surprising since the cerium oxide is itself unusual, yes, remarkable, in its behavior. My conclusions by means of which it was possible to separate the flesh-colored $Ce_2(OH)_6$ from the $Fe_2(OH)_6$, having the same color and characteristics, are disregarded unjustly. This applies only to the cerium oxide while the other ingredients of the clay are estimated by the ordinary analysis.

Why it is that my special method which met with very good success should be so arbitrarily rejected I shall not attempt to judge, since it does not come under the head of chemistry. Permit me, however, to mention that the complete omission in the criticism of the later results obtained by my method as reported in No. 23–24 (double number) of the *Technical Notes for Painting* seems very peculiar.

These are:

1. Reduction of the Ce_2O_3 in fused potassium or sodium carbonate, etc.; precipitation of Ce_3O_4 as oxalate with its splendid reaction.

2. Separation of the flesh-colored $Ce_2(OH)_6$ with ammonium carbonate from the $Fe_2(OH)_6$.

3. Preparation of larger quantities of lanthanum sulphate for commerce.

I realize the usual opposition to a little reform which, in this case, by being the first to find $Ce_2(OH)_6$ in nature, was unavoidable.

In regard to the remark about didymium there is nothing to be said since this metal is only to be found here and there in the Hainstaedt cerium clay corresponding to the fact that its presence cannot be shown in every orthite analysis.

DR. JONAS RUDOLPH STROHECKER.

FRANKFORT, August 23, 1886.

To this explanation of Mr. Strohecker I have the following remarks to make:

I am glad to find that Mr. Strohecker is also unable to find the cerium oxide and those of the other rare earths in the ordinary method of analysis, but it is not clear to me in what way he does get them. I know of no other method to discover an ingredient in the raw material than the ordinary method of analysis. Truly, one would not ordinarily look for the oxides of beryllium, yttrium, cerium, lanthanum, and didymium in clay; however, if we suspected that these were present we could easily show whether they were or not. These oxides, especially, have such a characteristic behavior and the reactions are so sharply marked that an extraordinary method for discovering them seems entirely unnecessary.

What is accomplished by this extraordinary method? If it is a case of showing minute traces of such rare bodies where the ordinary reactions are insufficient or permit of doubt in the presence of these, one would use sharper methods than the ordinary analysis by precipitation and titration; for example, spectrum analysis. This is, however, not the case here. Mr. Strohecker thinks he has shown unusually large quantities of these bodies. However, as long as these cannot be found by the ordinary method of chemical analysis we must consider them as not present at all, and Mr. Strohecker also did not possess them.

What method has he used in order to obtain them? Is it founded on science? What is the object of boiling a clay with strong alkalies when these are not able to decompose it completely? Mr. Strohecker must know that in boiling a clay with strong alkalies a great many things will dissolve but not to such an extent that they can be determined. He knows that alumina, silica, and ferric oxide as well as the never-failing organic matter, may dissolve but none of them so completely that the method can serve for a practical estimation of any one of them. Where does he prove an accurate analytical process in his method? Why is he compelled to use three different operations in obtaining the cerium oxide when he could obtain it in the ordinary analysis in one? These seem to show an infinite defect in his method, and how does Mr. Strohecker manage to attribute to the oxides, which he says he has found, new properties, as, for instance, the solubility of cerium oxide in potassium hydroxide? Above all, one must first possess the genuine substances and must really prove their identity. If, however, Mr. Strohecker himself could not find these by analysis, and in order to find them had to resort to so extraordinary a method, we would say that he never had them.

Of what value is his further discussion of the technical utilization of his assumed discoveries if one cannot find these substances by analysis, that is, if they are not present in the raw material? Is it possible to use, technically, something that one does not possess and cannot obtain? This is the first requirement of technical development.

I shall assume for the benefit of Mr. Strohecker that his assumption is only the result of a lively imagination of no value to science and that he really does think that he has found these rare earths in the clay. Compared with mine the figures of his analyses, that is, the silica and iron percentages, allow of another less honorable interpretation. However, on account of this variation they can be of no value scientifically or technically.

PROF. DR. H. SEGER.

BERLIN, August 28, 1886.

Some Fusion Tests with Standard Seger Cones

STANLEY G. BURT, TRANSLATOR

The standard cones[1] of Professor Seger, head of the Chemical Technical Experimental Station at the Royal Porcelain Manufactory, or rather the tetrahedra, as he calls them more accurately, which were so long desired and so necessary, were hailed with pleasure in ceramic circles, since it was hoped to obtain with them a fixed basis of comparison, especially with the upper numbers of the series for high temperatures, though below the melting-point of platinum.

Greatly interested, the writer at once made experiments, the results of which have been held back for some time, in the expectation that exact temperature determinations of the melting-points of the cones or on the method of their use would be published by the originator himself or by others. Since this has not been done, with the exception of a recent brief contribution from Dr. Heintz (*Thonindustrie Zeitung*, 1887, No. 1), these determinations and observations are now published without claiming for them, however, an exhaustive discussion, but merely to publish certain facts and the conclusions arising from my experiments and to induce further interest and a general exchange of experiences with these cones, especially from the large users.

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[1] It is well-known that feldspar cones have been tried here and there in factories for a long time and the Brieg fire-clay works made cones from spar, kaolin, clay, etc., certainly more than ten years ago, but Seger deserves the credit of having gone much further and having completely tested the composition of a great number of such cones in a systematic and "stoichiometric" manner.

The standard cones, that is, the ten highest numbers (Nos. 11 to 20), I obtained from one of the best known German fire-clay works, which, at my suggestion, obtained a number of these for the determination of their temperatures.

Small pieces pinched off were used in the experiments, since otherwise in my Deville furnace I would have been unable to burn a larger number of the cones at the same time in the same crucible. The fusion determinations were begun on the basis assumed by Seger. He takes the fusing-point of the hardest cone (No. 20) to be at about 1700° C. at the so-called approximate melting-point of platinum (seventeen to eighteen minutes' burning),[1] but which by no means equals the true melting-point for which the furnace must be in glow at least twenty minutes. His cone No. 20 would thus be equal to the temperature at which the 10 per cent. standard clay has fused to a drop of enamel. All the standard cones have fused to a colorless mass of glass, more or less vesicular. The same complete fusion of the cone pieces occurs in a burn of four minutes in which the standard 10 per cent clay has melted to a sphere with a vesicular fracture. The glass from the various cones is also more or less vesicular.

On decreasing the temperature uniformly during intervals of two minutes down to half-minute intervals, thus constantly decreasing the time and the temperature at fixed intervals, in twelve minutes or a temperature in which the cylinder of the above-mentioned standard clay was barrel-shaped, and showed a shining surface while the fracture was slightly pumice-stone-like, the following observations were made on the cones. All of them are again fused down and form, in part, glasses as in the preceding harder fire. The glazes from cones Nos. 11 to 16 have spread, while with Nos. 17 to 20 the fusion has not gone so far, these being more or less spherical, and forming a milky glass or a transparent white enamel which is especially noticeable in Nos. 19 and 20.

In ten minutes or at the temperature at which the standard clay trial was only somewhat deformed with a glossy surface and a vesicular fracture, all the cone pieces were melted down: Nos. 11 to 15 have spread out while Nos. 16 to 19 form merely pearls of white enamel; cone No. 20, as previously, held its shape better.

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[1] The number of minutes refers to the burning in the Deville furnace which I have described (*Deutsche Töpfer und Ziegler Zeitung*, 1884, No. 45). The counting of the minutes begins with the moment in which the flame appears through the glowing coke.

In eight minutes' burning or at a temperature at which the standard clay was somewhat swelled (of barrel-shape with but a slightly glossy surface), the fracture being vitrified and vesicular, Nos. 11 to 16 had fused down to drops. Nos. 17 to 20 are like pearls.

In six minutes or at a temperature at which the standard clay retained its shape with a grayish white surface, showing a vesicular fracture, the trials were fused to a drop-like or pearl shape. Nos. 11 to 15 were fused to drops, while Nos. 16 to 20, although glazed, still showed traces of the angular shape. The glazing of Nos. 19 and 20 is less apparent, while the edges of No. 20 are quite noticeable.

In four minutes or at a temperature at which the standard clay is but slightly deformed, with a grayish surface and vitrified vesicular fracture, cone No. 11 appears angular and less fused than Nos. 13 and 14. Nos. 16 to 20 are angular and glazed.

In three and one-half minutes or at a temperature at which the standard clay maintained its shape, covered with a matt skin and with a stone-like fracture, vesicular, No. 11 again appears angular while Nos. 13 to 15 are like drops, No. 16 somewhat angular, No. 17 more in the shape of a drop, and No. 18 angular but fused. Nos. 19 and 20 are sharply angular; that is, cone No. 11 is certainly and again more refractory than Nos. 12 and 13.

In three minutes palladium, that is, a thin piece of this metal, enclosed in pure alumina and also a piece not protected, has fused to a ball. The standard clay appears in its outer appearance and in its fracture just as it did in the three and one-half minutes' burning. All cones are glazed or have begun to fuse. No. 11 is angular, and Nos. 12 and 13 are rounded while the rest are angular.

In two and one-half minutes palladium was not melted;

cones Nos. 12 and 13 were rounded but all the rest were angular and glazed. Nos. 19 and 20 only showed traces of fusion.

If we now sum up the conclusions from these results they are as follows:

1. The standard cones, and even the highest number (No. 20), fuse at a temperature far below the fusing-point of platinum, at a temperature which can not even be said to approach the fusing-point of platinum.

2. The fusing-point of cones Nos. 13, 14, 15, and even 17, is not far above the melting-point of palladium; that is, not much above a temperature of 1500° C.

3. The cones at a reduced temperature show many irregularities among themselves; that is, some higher numbers melt before lower numbers, for example, cone No. 11 is much harder than the following two or even three cones, and again cone No. 17 is more easily fusible than No. 16 which precedes it. These partial contradictions in the assumed increasing refractoriness of the standard cones must necessarily lead to many deceptions in their use.

DR. CARL BISCHOF.

WIESBADEN, January 8, 1887.

Reply by Dr. Seger

STANLEY G. BURT, TRANSLATOR

In No. 2 of the *Töpfer und Ziegler Zeitung*, Dr. Bischof publishes some work on a section of the series of fusible pyrometric cones which I made public a short time ago. His object is to estimate the maximum temperature which can be fixed in ceramic kilns, by means of these and also the fusibility of the separate numbers with respect to each other. However pleased I am to see scientific and practical efforts working towards the same end in explaining phenomena in the technical field, confirming or disproving the observations of each other, still I regret this work, coming, as it does, from a scientific man, because it does not seem to me to have been carried out in as scientific a manner as I would have expected from him.

Dr. Bischof estimates first the exact fusing-points of the cones and finds that the melting-points of Nos. 11 to 20 are partly above and partly below the fusing-point of palladium (1500° C.), but that the fusing-point of platinum is not reached by far. As the result of a crude investigation this is, on the whole, correct. I will cheerfully acknowledge that I do not know whether the fusing-point of cone No. 20 is 50°, 100°, 200°, or more, below the fusing-point of platinum; yes, I acknowledge freely that I do not know an exact, indisputably, correct fusing-point for platinum since the results given by various investigators vary between 1550° C. and 2700° C., leaving a wide field for speculation to every one.

If I have assumed the fusing-point of cone No. 20 to be at 1700° C., and that of platinum, based upon the latest investigations, at 1775°, it might be said that this estimation is too low and that the difference is greater; however, he will always be in the right who makes the assumption since no absolutely correct one can be made.

I made this assumption from the impression which the heat makes on our eyes as we observe it in our porcelain kilns. If now Dr. Bischof estimates the fusing-point of platinum, according to his fire (which he certainly cannot follow with his eye), to be higher, that is, the difference to be greater because the interval of time which was necessary to produce this temperature and which he takes as a measure (twenty minutes to reach the fusing-point of platinum, but only eight minutes to reach that of cone No. 20) is greater, I wish to call his attention to the fact that at higher temperatures a slower increase in temperature must result and that the temperature increment decreases more and more, and finally that with the fusing-point of platinum one has almost reached the limit of the Deville furnace. If one does not have suitable coke (loose open gas coke), but uses dense melting coke, he will be unable to reach the fusing-point of platinum at all, although the blast may work for many hours. There is, however, no object in producing such refractory cones;

on the contrary, I have followed the practical demands. The melting-point of cone No. 20 corresponds, as far as I know, to the highest temperature used in ceramic work; it would, therefore, be useless to make more infusible cones. At this high heat, even when using dark-colored glasses, one can hardly watch the melting-point of cone No. 20, and then only owing to the temporary appearance of a thin flame is it made visible. Hence, there is no practical object for making harder cones. However, I will agree to make these harder cones as soon as Dr. B. provides me with a means of making them visible in the heat, since upon this hinges their practical value.

As to the second point in his article concerning the fusibility of the various numbers, it is astonishing how crudely and summarily he has worked. Aside from the fact that I do not consider the Deville furnace, however useful it may be in estimating the fusibility of clays, as suitable for such an experiment, or I myself would have used it for this purpose, he ought to have furnished proofs that in his little Deville furnace the temperature advanced with perfect uniformity and was uniform on all sides of the little crucible. He neglects to produce a scientific proof of this since he must know from his tests that it is not the case. A few hundred degrees more or less amount to very little here. In determinations of fusibility which I have repeated many times with the same material in order to check my results, I have often found pronounced variations in the heating of the crucible sides and of the little tetrahedra. This is quite natural. One can obtain a uniform fire only in a large kiln since the heat losses in a small one increase with its smallness. In the Deville furnace, which has a grate surface with a diameter of but 10 to 12 cm. and a height of 18 cm., the kiln space is, of course, very small. At the bottom (above the blast) the fusing-point of platinum may be reached, but above at a distance of 12 cm. the temperature falls to at least the fusing-point of silver; in the horizontal direction there prevail similar conditions.

The increase in temperature depends on the air forced in by a bellows. It should be proved that the air is uniformly distributed as it passes through the coke; if it does not pass through uniformly, which is probable or certain, it seems to me that the temperature which is produced in the various parts by combustion will also be irregular. It is my opinion that Dr. Bischof could not have found a more unfavorable apparatus for his temperature tests, however crude they may be. The real object in formulating this series of cones has escaped Dr. B. He fuses down the trials completely and then considers the resultant as glass pearls. However, this would be absolutely insufficient for practice. On the contrary, the first melting down due to their own weight must be observed; what becomes of them afterward, how the bubbles are distributed, and such useless phenomena are entirely immaterial. The experiment must therefore be made with whole cones, not with pieces the size of a pea. If Dr. Bischof will read over my treatise he will find that I made my experiments in the kilns of the Royal Porcelain Manufactory, that is, in kilns which, as far as the uniformity of heat is concerned, cannot be compared with his; hence, under much more accurate conditions. I would not have published the results had I not been convinced that the melting-points of the cones followed in the order of their numbers.

Had Dr. Bischof made his fusion tests in the same manner in a practical kiln I would have had to take the results as he found them; but it is useless to undertake these in a laboratory since it is impossible to carry them out there. They had better, therefore, be left undone. I myself did not test the melting-points in the laboratory but in the kilns of the industry. I must, therefore, declare the results he obtained in which cones Nos. 11 and 17 were not in regular order erroneous. I have gone to the practical men, with whom rests the decision, with this in mind, and since last May have sent out about 13,000 cones to the private industry, and have probably in my own use melted down about 1,000 during the year. I expected suggestions from practical men concerning the use of these in large kilns,—advice as to their form and size, and the addition or omission of possibly a few numbers. As to the scientific side of the question, the practical man naturally would have no opinion, but I have at my command the whole range of temperatures and have not tested the melting-points once but constantly in the large kilns. As opposed to this work the crude experiments of Dr. Bischof amount to nothing. But one complaint reached me from practice, coming from a fire-brick works at which cone No. 13 showed a greater tendency to fuse than cone No. 12, while No. 11 (contrary to Bischof's results) had completely melted down.

Once or twice, successive cones have gone down together in my many burns. In the first case this was due to the fact that the heat reached the cones from different sides, which caused them to bend in different directions. These cones are made as tetrahedra (6 cm. high), with a triangular base, in a copper mold from a damp body; the exposed side of the tetrahedron is somewhat larger, the base being a right-angled triangle with the two smaller sides equal. The cones always bend toward the same side, so that the larger side with the number stamped upon it is on top. This is the direction in which, owing to their shape and thickness, they naturally bend and fall. If now, in placing them in the kiln, they are met by the heat or the flame in such a manner that the largest surface receives the most heat, this side will contract first and the cone will bend while later it will turn or even bend on the wrong side. Since, however, the bending is due only to its own weight in case it is met by the heat in the manner above described the center of gravity is changed toward the opposite side, and the bending of the cone will naturally be delayed. If two cones of the same number are placed beside each other in such a manner that the number side at one time is turned from the fire, at another toward it, the former will always bend first. Where this happens, irregularities may occur. This was the case at the factory which made the complaint. Whether the irregularity in fusion which I noticed was due to the same cause I could not determine, but I am certain it was. Hence, it is always necessary to set up the cones so that the number side always faces in the same direction.

PROF. H. SEGER.

Reply by Dr. Bischof

STANLEY G. BURT, TRANSLATOR

To the attacks of Professor Seger on some fusion determinations which I made of a number of his cones I reply in defense. In a measure I am satisfied since Seger grants the first main point of my conclusions, that is, that the highest cone No. 20, "does not by far reach" the melting-point of platinum. I will not, therefore, discuss his admission, accompanied, as it is, with certain circumlocutions which acknowledge the error. I said that the standard cones, even the highest (No. 20), fuse at temperatures which are much below the melting-point of platinum and cannot even be said to approach it, as this would seem to be proved conclusively in my experiments.

If in my almost daily burns a platinum wire embedded in pure alumina fuses to a ball under the most favorable conditions in twenty minutes and if, on the other hand, cone No. 20 does so in less than eight minutes, this is an enormous difference, which is further exemplified by the fact that the 10 per cent standard clay is completely melted down in twenty minutes while in eight minutes the same clay is scarcely swelled and assumes about the shape of a barrel. These are entirely fixed undeniable facts which can be proved experimentally by any one who cares to undertake the work.

I will now consider the second important point which Seger denies in such a sharp manner that I must come back to it again. He concedes, however, irregularities observed not only by others but also by himself which would at least indicate that especially between cones Nos. 11 to 17, to which I called attention, something is wrong; that is, some abnormal conditions exist. *Hic haeret aqua* in the system established by Seger. A fire-brick works found that cone No. 13 had a greater tendency to fuse than the preceding one, *i. e.*, than cone No. 12, which was formerly considered more fusible. Further, Seger acknowledges that two successive cones, not distinctly designated, however desirable this would be, have at times in his burning gone down together. He explains this in a manner which does not seem to preclude discussion, upon the ground of their bending in a certain direction, for which purpose the cones are given an unsymmetrical shape, and acknowledges that if these conditions are not considered in placing them, inequalities may occur. These observations may form the explanation for the results which I obtained and, though Seger has found these same conditions only in several instances, it is a warning for investigators to consider this important point carefully. If my results are not to be set aside entirely, my observations may be brought in a measure to agree with those of Seger. I also want to defend the care taken in my observations and in drawing conclusions from them, which I did not take from one or two experiments that might coincide by chance, but I made from four to six check burns. The repeated trials after burning three as well as two and one-half minutes always gave the same results, although appearing in different guises. However, the question put in different ways always gave the same answer or, on using a different simile, a different method of calculation always gave the same result, and the varying experiments may be considered as checks among each other.

I now come to the separate points of Seger's article written in as high a tone, as it is deeply offending. Seger calls my experiments "crude," not once but repeatedly and with increased force, although they were able to bring to light errors in Seger's work which may not be considered very great. Moreover, I must consider such a charge as a peculiar view of Seger about which I need not bother myself, since, aside from the honorable acknowledgment which came to me from the best known scientific men on the appearance of my book "Die feuerfesten Thone," a like charge has not been made by any of my patrons who number thousands. May not Seger's term of crudeness be synonymous with simplicity? My simple, therefore, easily and rapidly changed, methods, have been able to show that the melting-point assumed by Seger for cone No. 20 is much lower than 1700° C., and that it is closer to 1500° C., the exactly determined fusing-point of palladium, and again that there is no such thing as a broad vague field for speculation in regard to the temperature in the Deville furnace. If a platinum wire embedded in pure alumina fuses in my Deville furnace in twenty minutes and palladium in three minutes then the fusing-point of this cone corresponds to six or at most eight minutes' burning, that is, in a time which cannot be converted into exact degrees of temperature but which is fixed within reasonable limits. These tests must be made in a kiln whose walls are not eaten into by slag or where this attack has been but slight.

I have known for a long time that in the Deville furnace at higher temperatures a slower rise in temperature is observed, and this can be directly assumed from my latest experiments although the fact is not specially mentioned. When I say that in my burns in the Deville furnace the fusing-point of palladium is reached in three minutes and the fusing-point of platinum not until twenty minutes later, this certainly shows, although merely implied, what a rapid advance of temperature there is at first up to 1500° C., while above this (burning from three to twenty minutes in an interval of seventeen minutes), there is only an increase of 270°.[1] Therefore, it is evident that at first there is a very rapid advance in temperature but later only a slow increase. That special mention of this should be made by the opposing side seems to me merely verbiage which in no way detracts from the striking result here given, and in no way adds anything new. I will say further that the Deville furnace, when all the rules which I give minutely in my book "Die feuerfesten Thone," pages 103 and 104, are observed, can easily be raised to above the melting-point of platinum. One can even bring iridium to incipient fusion, so that it shows an increased brilliancy with a forced fire. I have not fused iridium completely, as yet, but it is probable that I will accomplish even this.

Seger charges in the same slurring manner that I have not given proof of the perfectly uniform advance of temperature in the Deville furnace; this, therefore, I cannot do without contradicting myself. As I explained above, such a uniform advance occurs by no means, but this is of no importance, however desirable it would be. What is of importance and is determinant is undoubtedly that in the neighborhood of the small testing crucible or in its interior a uniform temperature should prevail. However desirable it would be to have this apply to all points in the interior of the crucible both in a vertical and horizontal direction, this does not exactly occur, as was shown by experiments which I have undertaken and described, although this difference is not very great. By observing all the precautions as directed, a very uniform temperature is maintained in a horizontal direction and between two clays of different fusing-points, which are attached to the circumference of the clay disk alternating five times, no visible variation in the melting-points can be observed. Thus sufficiently accurate, yes, almost scientifically accurate, conclusions, and by no means errors, can be drawn from the results.

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[1] The melting-point of platinum found by Violle at 1775° C. has been accepted here.

Theoretically, it is true that the larger the interior of a kiln the less will be its loss of heat. However, there are certain other points of the Deville furnace to which I expect to return later. The wall 7 cm. thick radiates so little heat that immediately after fusing platinum in the furnace the outer wall may be touched with the hand without feeling any pain. The loss by the sides due to radiation is therefore very small with the rapid heating which we have here. From my experiments this kiln proved remarkable through its ready control, as is the case with no other, and it deserves, therefore, a high position for pyrometric investigations. Seger says of the Deville kiln: "at the bottom above the blast inlet the fusing-point of platinum is reached." This is, however, never the case; in fact just above the grate it is comparatively cool, the temperature being so low that a glass tube placed there does not fuse. The temperature is only high at a height of 5 cm., and the highest temperature which can be attained is at a height of from 6 to 7 cm., which corresponds to the zone in which the objects to be tested are placed upon the clay disk. With this in view I have a specially constructed crucible whose interior corresponds exactly to these conditions. The air which is furnished by a bellows is always controlled by a manometer which shows a pressure of 2.5 cm. water, whose variations never exceed 3 mm. Thus the most uniform distribution of the air through the coke, which is measured each time, is most carefully maintained by proper manipulation.

As to the fact of my not using the whole cone, only the tip, I have explained this in my introduction. In my opinion this is of less importance since in the estimation of the fusibility, the body of the cone must be more important and decisive than the cone itself, although, according to Seger's explanation, its form may influence the manner of its fusing. Irregularities, when the whole cone is used, are, therefore, not excluded and one must return to the body estimation for absolute knowledge. That the body of a higher cone should have a higher fusing-point than the preceding cone is naturally the foundation upon which the reliable utility of these cones must rest. If a contradiction is found here, though small, this must first be explained or removed; such an explanation seems to be demanded by these definite undeniable irregularities which should be traced to their cause.

I will close with Seger's most bitter accusation. He says that he denies my results and calls them erroneous. Aside from the gravity of such a charge among men seeking for exact results whose only object is scientific truth, I shall in another place produce proof that this word is as hasty as it was inadvised.

DR. C. BISCHOF.

Note on the Estimation of Temperatures in Kilns by Means of the Pyrometric Cones

STANLEY G. BURT, TRANSLATOR

To the letter of Dr. Bischof contained in this number I wish to make the following reply: Dr. Bischof endeavors to prove that I have in a measure satisfied him in acknowledging that my estimation of the melting-point of cone No. 20 as being near the fusing-point of platinum was not correct. Aside from the fact that I did not do this, it is a matter of no importance to me to obtain with the cones the temperature which Dr. Bischof describes as the approximate fusing-point of platinum, but I do intend to supply the demands of the industry by providing them with a means of showing to the eye (by the bending of a cone) the approach to the highest temperatures used. If I now assume that as far as I know cone No. 20 corresponds to the highest temperature used in ceramic work and describe it as near the fusing-point of platinum, I do not mean to say that the difference is one which can be expressed as yet by numerical values. The assumption of the fusing-point at 1700° is, of course, somewhat hypothetical, but the magnitude of the number I consider of no value, and I am ready to alter it cheerfully just as soon as the incorrectness of this hypothesis is proved scientifically. In proceeding like Mr. Bischof, however, such a proof will be impossible. He must know the relation between the temperature and the advance of the same per unit of time. This advance is, unknown to him: he only knows that it varies extraordinarily, and proceeds to put one hypothesis against another which proves nothing. For the practical use of the cones it is absolutely immaterial what numerical value is taken. This is not essential. It is essential, however, that the first fusion of the cone, making visible the approach of a certain temperature by the bending over of the point, corresponds to a fixed temperature and that these changes in shape are in the sequence of the numbers. Dr. Bischof has not tested this point at all and he could not do it with his kiln, but on the ground of his experiments, which I am compelled to call crude, he has endeavored to throw doubt upon my results. He undoubtedly has the right to test my work or to disprove it, and such testing would give me pleasure, but it would have to be done with apparatus equally or more reliable, otherwise it would be valueless and had better be left undone.

Further on he praises the Deville furnace which he used and its extraordinary scientific value. I must confess that I am of a different opinion on this subject. I value it as an apparatus by means of which investigations upon the fusibility and position of clays in the scale of refractory clays can be made with great rapidity, but further than this its usefulness does not reach. It is only possible to estimate the fusibility of a clay by placing the standard clay in the same crucible and then comparing how far the fusion has gone upon this or that clay which is being tested. Even with the most careful observance of the rules given, one always obtains but comparative results and is compelled, on account of the apparent irregularity of the temperature in the crucible, to repeat the trials many times in order to secure sufficient accuracy. I am not the only one who is of this opinion, since I have always heard similar conclusions from those who are occupied in making fusion tests. It is possible that others, as well as myself, have not been able to attain the same skill in handling the furnace that Dr. Bischof possesses, and it may also be possible that we make more stringent demands on it. I should think that I, who use it in testing almost daily (and I do not consider myself altogether unskilful), should learn in time how to operate it.

I have received communications from practical men, as a result of this controversy, in which they say that they agree entirely with my conclusions as to the melting-points of the cones. I have no desire to publish these since no exact data are given; they merely agree with mine. One letter (from Eugene Hülsmann, at Wurzen), however, I published (*Thonindustrie Zeitung*, 1887, No. 6), since it contained exact data. Another letter, omitting the introduction, which is on another subject, reads as follows: "This brings me to the article of Dr. Bischof on your cones; allow me to say in this connection that I never burn a kiln without your cones, and 200 of them which I used have always confirmed your results. Probably Dr. Bischof's error is due to his little test kiln. I burn your cones Nos. 1 to 17 and can justly say that they have done me great service."—*K.* in *W.* Messrs. Ch. Lauth and G. Vogt, in Sèvres, have also attacked this question and they confirm my results. In the *Moniteur de la Cèramique et de la verrerie*, they publish their experiments, and after explaining my method of preparing the cones they say:

"Nous avons vérifié les chiffres de M. Seger et établi la concordance, qui existe entre ses resultats et les nôtres." On the ground of these statements I look forward to Dr. Bischof's with calmness.

Note on the Standard Cone Question

SAMUEL GEIJSBEEK, TRANSLATOR

No. 10 of the *Toepfer und Ziegler Zeitung* contains an article, "Measurement of High Temperatures," copied from the *Journal du céramiste et du chaufournier*. Other French journals have reprinted the same article which contains some very grave errors that are thus being diffused. The article states: "Seger's error lies in the assumption that these substances, lime, potash, alumina and silica, are able to combine in any proportion, and that the fusibility of the mixtures is the mean of the fusibilities of the several constituents. Again at the end of the article it says: "As long as we do not know the exact composition of the mixed silicates, the preparation of these pyrometric cones can only be based upon experiments, not supported by chemical theories."

I wish to state that I did not make the very mistake here criticized; I fully believe that I have been the first to show that the theories of fusibility, as they are at present taught, do not hold good in practice. The simple increase in lime and potash does not increase the fusibility of the glass mixture, nor does the increase of alumina and silica decrease the fusibility, but a definite ratio must exist between these constituents. By experiment I have pointed out these deviations from the usual chemical laws, I have made cones from such mixtures, and have observed their behavior in the fire of a porcelain kiln. The results have shown that the increase in alumina and silica will raise the melting-point only if the ratios chosen by me are maintained, but that other proportions may give rise to grave errors. It is useless to talk about unexplained chemical theories, since I did not make use of any theory at all, but have been guided entirely by experimental work.

I believe I am justified in saying that the writer of the above article has never read my articles in connection with this matter, which were published in Nos. 14, 15 and 17 of the *Thonindustrie Zeitung*, in 1886. DR. H. SEGER.

Polemics Referring to the Seger Cones

In thelast issue of the *Toepfer und Ziegler Zeitung* the polemics in regard to the fusibility of the Seger cones, Nos. 11 12 and 13, find their conclusion. Dr. Bischof announces that he has mistaken cone No. 11 for cone No. 17, which was caused by the bad impression of the No. 7, which was taken for No. 1. Under such circumstances it was natural that the fire-tests of Bischof should have resulted as he has stated. Dr. Bischof sincerely regrets this mistake, which has led him "to doubt the value of Seger's work," and the accused declares himself satisfied with this loyal declaration. It is expected that the journals which have heralded the attacks on Seger's work by Bischof will give notice of the real situation, especially the *Journal du céramiste et du chaufournier*, which went so far as to doubt the entire principle of the cones, based on the experiments of Bischof.

It was, however, decided at once that the journal in question did not even read or understand the articles published by Seger, and the editors of the *Toepfer und Ziegler Zeitung* find themselves in the same boat when they copied, with great enterprise, the article the journal contained.

EDITORS OF GERMAN EDITION.

PYROMETRIC TESTS OF SEGER CONES IN DIFFERENT KILNS.

(Taken from *Sprechsaal*, 1888, No. 21.)

Kiln system.	No. of kiln chamber.	Fuel.	Ware being burnt.	Time of burning. Hours.	No. of cones.	Position in kiln.	Results.
Round kilns fired direct, 8 grates. Up-draft old construction.	1	Coal mine run, from Saar district.	Fire-brick for puddling furnaces.	83	4, 5, 6, 7,	Center of kiln.	4 and 5 bent together and also melted together, 7 bent 40 minutes later, 6 remained standing.
	2		"	86	4, 5, 6, 7,	"	Bent simultaneously and fused close together after 15 minutes.
	3		"	88	4, 5, 6, 7, Time includes water-smoking.		5 and 6 bent first, 4 after several minutes, 4 and 5 fused together, 6 to 20 minutes later. 7 remained standing with tips somewhat bent.
	4		"	89	4, 5, 6, 7,		4, 5 and 6 bent in intervals of about 15 minutes, fused simultaneously, 7 unchanged.
	5		Fire-clay ware.	64	3, 4, 5,		3, 4, and 5 bent and fused together immediately.
Méténier kiln, 2 story. Up-draft, 6 direct furnaces.	9 and 2nd story of 10.	As above, firing started with coke.	In No. 9, magnesite bricks from Styrian hard-burnt magnesite cemented by caustic magnesia. In No. 10, fire-clay ware.	114	10–20 1–10	"	10 and 11 bent and melted Oct. 5th, 8 P.M., 12-16 bent in short intervals and fused almost simultaneously within 38 minutes, after 12 had begun to bend, Oct. 6th, 5 A.M. On the same day, at 3 P.M., 17 turned and 30 minutes later fused down; 18 also turned and fused together 30 minutes later. At 8.30 P.M., 19 bent and fused almost simultaneously. 20 bent on Oct. 7th, 2 A.M. In No. 10, on Oct. 6th, 1-3 had fused down; all the others up to 10 remained standing.
Méténier kiln with only one story. Up-draft and 6 direct furnaces.	8	As above.	In No. 8, 2 tests, in each fire-clay ware and buff sidewalk tiles.	1st test, 142 2nd test, 108	1, 2, 3, 4, 5 1, 2, 3, 4, 5		Kiln No. 8, first test, 1 fused 2 A.M. Nos. 2 and 5 at 5 A.M.; after 2 had bent an hour earlier, 3 and 4 were bent and fused together after stopping firing. In the second test 3 bent and fused first; an hour later 1 and 2 simultaneously; 4 and 5 remained standing. The ware was better vitrified than in the first test.

PYROMETRIC TESTS OF SEGER CONES IN DIFFERENT KILNS—(*Continued*).

Kiln system.	No. of kiln or chamber.	Fuel.	Ware being burnt.	Time of burning. Hours.	No. of cones.	Position in kiln.	Results.
Kiln with bottom side and down-draft firing. System of Ehrhardt and Dr. Jochum 9 grates. Flame escaping through floor.	6	As 8, 9, and 10.	Buff sidewalk tiles, German iron bricks.	48, including water-smoking.	3, 4, 5	Center of kiln.	In kiln No. 6, 4, 3 and 5 fused and remained standing, the ware was burnt somewhat too soft.
	7			65	3, 4, 5, 6	"	In kiln No. 7, cones 3-6 remained standing.
Mendheim partial continuous kiln, gas fired; 8 chambers each 3.8 × 2.65 × 2.45 meters.	1	Gas.	Fire-bricks.	30	4, 5, 6, 7	"	Bent and fused simultaneously.
	2	"	"	30	4, 5, 6, 7	"	4 and 6 bent first and fused after 10 minutes, 5 and 7 remain unchanged.
	3	"	"	30	4, 5, 6, 7	"	Bent simultaneously and remained in this position without fusing.
	4	"	"	36	8, 9, 0, 0	"	8 bent first, fused 1 a.m., No. 9 fused 3 A.M., 10 remained standing.
	5	"	"	36	5, 6, 7	Left side.	5 fused 5.30 p. m., 6 at 6.30, 7 at 7.15, Nov. 18th.
					5, 6, 7	Middle.	5 fused 4 a.m., 6 at 4.45, 7 remained standing Nov. 19th.
					5, 6, 7	Right.	5 fused 12.15 a.m., 6 and 7 fused down 12.45 a.m., Nov. 19th.
Mendheim partial gas-fired continuous kiln 8 chambers each 3.8 × 2.65 × 2.45 meters.	6	"	"	40	7, 8	Left.	7 fused Nov. 20th, 8 p.m.; No 8 fused 1 a.m., Nov. 21st.
					6, 7, 8	Middle.	6 fused Nov. 21st, 1 a.m., No. 7 fused 2 a.m., 8 remained standing.
					6, 7, 8	Right.	6 fused Nov. 20th, 11 p.m., 7 and 8 fused together Nov. 21st, 2 a.m.
	7	"	Magnesite bricks	120	18, 19, 20	Left.	18 point fused round, 19 untouched, 20 fused down.
					18, 19, 20	Middle.	All 3 straight.
					19, 20	Right.	19 and 20 bent, 20 more than 19.
	8	Chamber 1 with mine-run coal up to red heat, then gas-firing.	Magnesite and dinas bricks.	112	18, 19, 20	Left.	18 and 20 fused down; 19 bent.
					18, 19, 20	Middle.	18 bent; 19 and 20 straight.
					19, 20	Right.	19 and 20 bent, 19 more than 20.
Hoffmann oblong continuous kiln with 18 chambers. Stack outside of kiln.		Slack and nut coal.	Vitrified bricks and chimney bricks up to 440 × 200 × 80.		1, 2, 3		In the entire cycle burn, the points of 1 and 2 were bent but once.

According to the above careful tests, the Seger cones are not sufficiently reliable to enable the determination of certain temperatures in the burning of ceramic wares.

DR. PAUL JOCHUM.

Pyrometric Measurements

SAMUEL GEIJSBEEK, TRANSLATOR

In No. 21, *Sprechsaal*, 1888, Dr. Jochum publishes a table of pyrometric tests with Seger cones in different kiln systems. Many of these tests give him results, which put the regularity of the cones in question, though in some tests the results were satisfactory as the cones melted down in regular sequence. Before I explain the possible reasons of the results obtained I would like to state that I do not doubt the results of Dr. Jochum. I have often found in the beginning of the adoption of cones in my burning, in which the conditions are far more favorable than in the kilns of Dr. Jochum, that I obtained results similar to his; however, that was before I paid sufficient attention to the precautions required in burning with cones. At the same time I have asked the manufacturers to test the cones in their practical work, and the above-referred article is valuable and desirable as it enables me to explain the question of pyrometric measurement, suggested by me.

As explained before,[1] I have chosen the chemical composition of the cones so that the content of the less-fusible ingredients, alumina and silica, increases with the number of the cones, while the content of the fluxes, potash and lime, and their ratio, 0.3–0.7 equivalent, remain the same. The ratio between alumina and silica remains always the same, 0.1 : 1 equivalent. We may assume that every higher number is produced from a lower one by the increase of kaolin and silica, this increase being at first small, but growing larger as the numbers become larger. I had to make an exception with the lower numbers, since it was proved that the composition of cone No. 4 was the most fusible mixture of potash, lime, alumina, and silica. An increase of the fluxes or a decrease of the silica and alumina, or a change in the ratio between potash and lime, or between silica and alumina, produced more infusible mixtures, contrary to the principles so far established. The fusibility could only be increased by the substitution of alumina by iron oxide, which was adopted for the lower cones (Nos. 3 to 1). No objections can be made against the gradual rising of the melting-point from a theoretical standpoint. I have only raised doubts in the above-mentioned articles in regard to the temperature differences between the cones, as to whether they are equal, and it was found that the difference between cones Nos. 4, 5, and 6 was relatively so small that it would possibly be preferable to combine these numbers. However, I concluded to drop this idea, since the cone numbers would then not coincide with the equivalent numbers of the acid content.

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[1] *Thonindustrie Zeitung*, Nos. 14, 15, 17, 22, and 23, 1886.

The only question to be considered was how these cones, computed according to theoretical principles, would behave under practical conditions, and whether they would allow us to estimate with sufficient accuracy the temperatures required in the burning of ware. I believe I can answer this question in the affirmative, judging from the number of cones already used in the industry. I have supplied these cones in the past year to eighty different firms with a total of 20,277 pieces. Complaints or suggestions of changes have not been made to me, except the one from Dr. Jochum who warns against their use, and a great many firms are supplied by me with cones. At first, some unsatisfactory results were reported (three in all), but these could be traced back to improper handling. In our own use of the cones such irregularities as observed by Dr. Jochum have never been encountered. I hence draw the conclusion that the cones have met the requirements for which they were made. For example, my kiln burners would be helpless in case they could not have cones to mark the necessary firing temperature.

I believe that the irregularities in the melting of the cones as observed by Dr. Jochum can be traced back to the unevenness of the fire in the kiln, similar to some previous cases. I do not intend to hold the kiln burner responsible for this as irregularities are natural, and are defects which will show up in more or less pronounced form according to the kiln content. In burning, heat is produced by the chemical process which takes place between the constituents of the fuel, carbon and hydrogen, and the oxygen from the atmosphere. The heat is transferred to the ware which is to be burned by the gaseous compounds produced —carbon dioxide, steam, oxygen and nitrogen. It is natural that these gases are much hotter than the kiln content, otherwise it would be impossible to obtain an increasing temperature. It is also necessary that the volume of the gases should be very much greater than the kiln volume. One cubic meter of kiln content, filled with fire-brick, as in the case of Dr. Jochum, weighs about 1050 kilograms; one cubic meter of air at 0° C. and 760 mm. barometric pressure, weighs only 1.293 kilograms, and is reduced by heating and expansion to about one-tenth; consequently the weight of the kiln content is many thousand times greater than the air which brings in the heat, and the latter must hence move with considerable rapidity between the solid ware. This transfer of heat from the rapidly moving air makes it necessary that the latter be always much hotter than the ware, and the air will be the hotter, the greater its velocity; the sluggish air currents will, however, assume the temperature of the ware. We speak of a "flash" flame, when the rapidity exceeds a certain limit, and when the introduction of heat is greater than the distribution to the kiln content by conduction, and radiation which does not take place suddenly but slowly. The effect of such a "flash" flame can be seen on every brick pile, on every brick, and it is not necessary to explain this. The flashed portions cover sometimes only an area of a few centimeters or millimeters. Unless Dr. Jochum has taken proper care and kept his cones in places where they would be surrounded by slow or stationary kiln gases, he has not measured the temperature of the ware, but the much hotter temperature of moving gases. His tables do not throw any light on this subject. If a cone was placed above the openings between the bricks, so that it was surrounded by a rapid current of hot air, it naturally melted down sooner than its neighbor, which was protected from this heat. If Dr. Jochum will bear these questions in mind in continuing his experiments, and will place the cones so that they are protected from the "flash" flame, he certainly will obtain different results, and he will be convinced that the measurement of temperatures by means of cones is not as defective as he has said in his warning.

I want to call attention to the fact that as an indication of the temperature reached the mere bending of the cone is not sufficient, but only the moment when the top of the cone touches the bottom of the tile on which it is placed. The cones are made from a raw clay body, which naturally vitrifies long before fusing, and which will consequently be bent somewhat. An exact observation can be made only when the melting has actually commenced.

PROF. H. SEGER.

The Coloration of Clay Products by Iron at High Temperatures

SAMUEL GEIJSBEEK, TRANSLATOR

We publish herewith an article by Professor Seger on this topic, which resulted in a polemic between him and Professor Knapp, of Brunswick. For the better understanding of the article, it will be necessary to reproduce the three articles of these gentlemen already published in the *Chemiker Zeitung*, 1888. The first article written was anonymous.

I.

There is much truth in the statement of A. W. Hofmann, recently used in a letter from an industrial exposition, that the chemistry of the igneous processes is yet to be established. It is certain that the course of reactions is quite different at high than at low temperatures this side of red heat, and in the wet condition. The technologist will make a great mistake when he judges the operations of igniting and melting at high temperatures, by his school knowledge obtained from wet reactions. We often find such mistakes in articles pertaining to the glass and porcelain industry. In the last issue of the *Thonindustrie-Zeitung* we have a similar case. It is stated there that certain English kaolins contain but a small quantity of iron which always gives to porcelain a yellowish cast, or a bluish color under reducing conditions. Experience does not support this statement; it is next to impossible to color porcelain yellowish or bluish with iron.

Ferric salts are yellow, and ferrous salts bluish green, the former being peculiar to oxidizing, the latter to reducing firing; certain things are colored yellow by ferric oxide and bluish green by ferrous, but porcelain in the glost burn, never. Only one combination of iron with oxygen is stable at the high heat of a porcelain kiln, not the ferric or ferrous oxide, but magnetic iron oxide (Fe_3O_4), and this will never give yellow or blue, but in proportion to its content, all shades from gray to black. It is, however, very true that yellow is the usual color of spoiled porcelain, but this is not due to the iron but to the smoky (reducing) fire, involving the reduction of the sulphates to sulphides (Na_2S, K_2S). The fire of a porcelain kiln is not a blowpipe, and the 10 cwt. of porcelain contained in it no borax bead, which we can move to and fro in the flame — the temperature of the porcelain kiln will fall at once with a shortage or an excess of air, below the high finishing temperature; the burner, hence, has not much room for variations between reducing and oxidizing conditions. These assumed differences, therefore, will not play a very great rôle in the porcelain kiln. The behavior of the iron in glass-pots is not different and only the magnetic oxide is produced. Ferric oxide (Fe_2O_3), added to molten glass in sufficient quantity, will crystallize out on slow cooling as magnetic oxide (Fe_3O_4). Glass-mixtures at low temperatures may show, of course, a yellow color due to undissolved, suspended ferric oxide.

II.

Under the above caption, No. 12 of the *Chemiker Zeitung* brings an article in which the author gives his opinion with great assurance in regard to the coloration of porcelain, which is obtained at a high heat, and in which he denies the coloring-power of the iron compounds. The statement of A. W. Hofmann first quoted may be true; the author, however, is in error in regard to the process involved. We do not possess any clay material which is used in the manufacture of porcelain, which is absolutely free from iron. The best white porcelain never contains less than about 0.5 per cent of ferrous oxide, and the greater part contains 1 per cent and more. The stronger colored porcelains of China and Japan, which are more yellow than the European porcelains, contain up to 2.5 per cent. This content of iron, which is always to be found in porcelain, must be regarded as the coloring agent. The yellow color is produced by the ferric oxide and the bluish green by the ferrous oxide which are produced according to the nature of the burning process. The gray color can be observed only in the easily fusible porcelain, and it is due to a mixture of both oxides; it does not occur very often. The yellow color is the more pronounced, and the blue-green can only be observed in the translucency. Porcelains containing 0.5 per cent iron oxide have a distinct yellow color when burnt under oxidizing conditions, while this color will nearly disappear in the reducing fire. The porcelain which I am manufacturing contains 0.5 per cent of iron and always has a slight yellow tinge when fired under oxidizing conditions. The glaze which is colored with ferric oxide is also yellow to yellowish brown. That I have been able to maintain oxidizing conditions is shown by the fact that I am making glazes colored with uranium oxide, copper oxide, and tin chromate, which would be worthless if burnt in reducing gases, the yellow, green or pink color of the glaze being destroyed. In order to obtain the Chinese-red cuprous oxide glaze I maintain reducing conditions, and this will always color the body white or bluish green; likewise, the iron glaze is changed to blue-green. Burning the same ware again in the oxidizing fire will always color it yellow, owing to the oxidation of the iron to ferric oxide. The color which is shown by green Indian or Chinese Seladon porcelain, is due to a content of ferrous oxide in the glaze of from 1.5–2 per cent. White, normally burnt porcelain will assume a yellowish cast by oxidation on cooling the kiln slowly. It is therefore the usual practice to pull down the doors directly after finishing the burning of the continuous kiln, where the cooling takes place much slower than in the ordinary up-draft kilns, in order to cool the porcelain quickly till the glaze is chilled.

I have never observed the yellow color due to the reduction of sulphates; this will only happen in very basic soft glazes, but never in very acid silicates to which the porcelain belongs. The iron glaze (6 to 8 per cent) of the yellowish brown Bunzlau stoneware is always green or black on the fracture, owing to its being burnt in the reducing fire; the surface shows yellow crystalline separations of ferric oxide or ferric silicate, due to the oxidation during cooling, of which the author can convince himself readily by a microscopic examination. It is useless to speak of the stability of magnetic ferrous oxide; it changes, according to reducing or oxidizing conditions, in the presence of silica, to ferric and ferrous oxide, and in the absence of silica to the metallic form. The same applies to the colors of glass: the yellow and yellowish red color is due to ferric, the light green to ferrous oxide, and a mixture of both runs through all shades from dark green to black. If the author has never seen porcelain colored yellow by oxidation, I am very willing to produce specimens for his inspection. PROFESSOR SEGER.

III.

The article in No. 12 of the *Chemiker Zeitung* in regard to the coloring of porcelain in the glost fire was aimed to arouse opinions as to the value of a principle, which is contrary to empiric facts as they are known to-day. It is a principle which, if represented by such a successful investigator as Professor Seger, who occupies an influential position, may lead astray men who think along these lines.

The reply in No. 18 proves much for the firm hold of this principle, but not much as to its truth. From a piece of yellow-colored porcelain "colored by oxidation," which Professor Seger offers to send, it might be concluded that this phenomenon of yellow coloration appears also in Charlottenburg, but this piece would not prove that the yellow cast is due to oxidation, and especially would it not prove that it is due to iron. Professor Seger states that all kaolins, hence all porcelains, contain iron; porcelain is therefore liable to assume a yellowish cast when burnt. Two absolute unchangeable facts, and the conclusion drawn is just as reliable. If a porcelain contains iron, and is colored yellow in the fire, it cannot be concluded that the iron was the coloring agent, and that there can not be another cause. The experience of all porcelain burners in all parts of the country shows that the yellow or white color of the porcelain is due to clean or smoky fire. It is commonly accepted that smoky fire causes the formation of sulphides from sulphates, owing to the fact that potassium and sodium sulphides color glass yellow.

Impossible, says Professor Seger, in an acid silicate like porcelain. This opinion is only a piece of doctrine, the opposite of which was proved by Dr. Ebell, in 1878, who says: "All glasses, the acid and the neutral ones, are colored yellow by alkali sulphides; the acid glasses resist only the yellow coloration due to sulphur, but not the color caused by the alkaline sulphides." Against such erroneous conclusions in regard to the action of iron in the burning of porcelain must be put the plain fact that iron, its oxide, is a means of coloring porcelain gray. The writer had occasion to observe some experiments which were made with special regard to these points; a series of trials of the same porcelain body were mixed with increasing quantities of red oxide of iron and fired. They resulted in a consistent series of shades of gray. It happens occasionally that iron filings (from pulverizers or files) get into the porcelain. Will Professor Seger maintain that such particles of metallic iron will produce a yellow speck in the porcelain? Hardly, since he knows that in such instances only black specks will result. All chemists are of the opinion that iron in the ferrous state colors more intensely than its equivalent of ferric oxide; simple experiments show this. Only to accommodate Professor Seger, must the iron act contrary to this experience, and the ferrous oxide, while hardly noticeable, should color intensely as ferric oxide.

Professor Seger tries to extend his doctrine to the glass manufacture, a branch from which he is removed and of which he is not able to speak authoritatively. He says: "The same is true for the coloring of glass; the yellow and yellowish red color comes from ferric, and the blue-green from ferrous oxide." In reality ferric oxide always colors glass (without any addition of other materials like manganese) green. A visit around the corner to the bottle factory at Charlottenburg should have proved to Professor Seger his error, and would have taught him that ferric oxide never colors glass yellow but always green. Why does not Professor Seger make some experiments on the coloration of glass with ferric oxide, when he has so many crucibles and so much fire at his disposal? He will find that oxygen is generated at the same time. All these facts are clear, and can be found recorded in the literature. It will also be found that white glass melted with iron is able to dissolve so much of the latter that the greater part, on slow cooling, crystallizes out as magnetic oxide.

The working of the iron in the open hearth and puddling furnace is without doubt an oxidation process, which Professor Seger admits. Is the result ever ferric oxide? Is the iron slag anything else but the stable ferroso-ferric oxide together with the silicate?

It is our sincere wish that preconceived opinions might be given up at Charlottenburg. They cloud the judgment and the healthy decision between simple opinion and real facts. A doctrine is not proved by being repeated as in the reply. If the behavior of iron at the high temperatures of the porcelain kiln or glass pots were still unknown, and beyond the range of experience, it might be expected that all chemists would agree with Professor Seger, and would expect that ferric oxide colors the glass yellow. This would be a preliminary opinion not without foundation; but the spirit of research requires that we compare the *à priori* opinion with concrete facts, and thus arrive at the truth.

PROFESSOR KNAPP.

In answer to the above, Professor Seger writes as follows: In No. 26 of the *Chemiker Zeitung*, 1888, Professor Knapp publishes an article which deals with the same subject as the articles published in Nos. 12 and 18. The rather sharp tone of the first article caused me to reply in the same manner. Since I now know the name of the author, I shall not follow the tone of his article, but will confine myself to the facts.

The author will be, with me, of the opinion that scientific questions are not solved in this way, and that personal attacks render discussion very difficult. I cannot change any of my opinions, even when the contradiction comes from such an eminent, scientific and practical man. They are the result of ten years' practical experience in the manufacture of porcelain, and any one who knows me will testify that I do not believe in advancing doctrinism.

It is decidedly erroneous to assume that the yellow color can be traced back to the reducing condition of the fire. It is well-known that bricks which are manufactured from clay containing a high percentage of iron, when burned, will assume a red or yellow color as long as they are still porous. Theoretical and practical men attribute this to the presence of ferric oxide in the clay. When, at the beginning of cooling, the trials are gray in color, showing the lower oxidation of the iron, this color may be changed to the color of ferric oxide during the cooling by the action of the oxygen. If the bricks are to remain gray or black, they must be "smoked." This is accomplished by the action of hydrocarbons till the ware has been cooled below red heat, or by the use of wet wood, producing a reducing atmosphere. When the "smoking" is stopped too early, the results are red and yellow bricks. The gray color is produced by the reduction of the ferric oxide to ferroso-ferric oxide or metallic iron, which also causes the separation of graphite. Every brickyard proves this. If, however, the burning is carried as far as the closing of the pores, that is, vitrification (as in porcelain), after reduction has taken place, it is impossible or difficult for the iron to be reoxidized to ferric oxide. The vitrified bricks have a black, blackish green, or gray color at the fracture, and only the surface is red, reddish brown, yellowish brown, or yellow. However, if the oxidation has taken place at the closing of the pores, the fracture will have the same color. Every brick kiln will prove this fact.

Brick clays have a content of ferric oxide varying from 3 to 15 per cent, and the different shades of color are dependent on the fineness and the quantity of the iron present, the duration of the burning, and the composition of the clay itself. The same applies to the materials lower in iron used in the manufacture of fire-clay ware. These clays often do not contain much more iron than the clays used in the porcelain manufacture, and are always whitish yellow to yellowish brown in color. In these products the trials drawn are nearly always gray, the yellow color being produced by the action of oxygen during the cooling. When such clays low in iron are burned to vitrification, as in the stoneware industry, they will show on the fracture a yellow (oxidizing), grayish blue or light gray color (reducing), according to the manner of firing; the surface will always be yellow, owing to the oxidation of the iron, unless the glaze is too heavy. Any mineral-water bottle will prove this.

When, in the beginning of the 70's, the continuous gas-fired kiln was built at the Royal Porcelain Manufactory, it was observed that the porcelain burnt in it always showed a stronger or weaker yellowish color. Dr. Hertzog, who died as the director, was at that time the chemist, and he concluded quite right that the yellow color was due to the long-continued action of the highly heated air on the porcelain. Since then, every finished chamber is cooled by opening the top flues, and tearing down the door directly after the porcelain is burnt, thus chilling the glaze quickly. This process is still employed, and all attempts to save this loss of hot air have proved useless. Even to-day our single kilns, like the kilns of the private industry, are burnt with a reducing flame up to the vitrification and incipient fusion of the glaze, about the melting-point of feldspar, this being proved by the nearly unbearable smoke from the porcelain kilns. Only when the admission of the air to the interior of the ware is prevented by vitrification, is it permissible to burn with a neutral flame, in order to produce the required high temperature. All those potteries which have experimented with total smoke consumption have had some very expensive experiences in regard to the yellow coloration of the porcelain. This is not a doctrine, but a statement taken from every-day practice.

I always burn my porcelain under oxidizing conditions since the metallic oxides which the glazes contain are easily reduced, like copper oxide, uranium oxide, and the chromium compounds. This is proved by the stack which never smokes, and the gas analyses which I have carried out for years, and which were made about every half hour. They show an excess of oxygen of from 2 to 8 per cent. Similar analyses have been made in the kilns of the Royal Porcelain Manufactory, by the director, Dr. Heinecke, for several years. There is also no doubt in regard to the composition of the kiln-gases. They have shown that the yellow color is always produced when the atmospheric air has acted on the ware before vitrification, but that the ware is white when up to this point a reducing atmosphere has been maintained. My colored porcelain always possesses a cream color where it is covered by a white glaze, while in the reducing fire it becomes pure white in color.

Every practical man can testify that it is impossible to obtain yellow or cream-colored porcelain without oxidation. It is impossible to explain how Professor Knapp can bring the easily decomposed alkaline sulphides in connection with the yellow color. What is true of the coloring of brick and fire-clay products is certainly applicable to porcelain. It is not at all proved that a yellow color is produced in a reducing atmosphere with alkaline sulphides in very acid glasses. It has only been proved that the color can be produced readily by basic glasses, that is, bisilicates, but difficultly in acid, tri- or tetra-silicates. The glass industry does not possess any higher acid silicates since these would not produce clear glasses. The porcelain glaze has the following composition: RO, 1.0 to 1.2 Al_2O_3, 8 to 12 SiO_2, which is certainly much more acid. With such glasses, Ebell has never experimented in regard to color. The possibility of the yellow color is rendered doubtful by the practical experience of the porcelain industry. The former glazes of the Royal Porcelain Manufactory were high in sulphuric acid (plaster-of-Paris glazes) but they did not give any more trouble than the present glazes in which marble is used, free from sulphates. It is a fact that in the reducing fire we obtain white or slightly bluish green porcelain; in the oxidizing fire, always a yellow color. Mr. Knapp speaks of clean and smoky fire; this, however, is too indefinite without statements based on gas analysis. To build a theory on facts not yet proved does not seem to me to be in harmony with natural science.

Professor Knapp maintains that iron oxide colors porcelain black. I will concede this from a superficial standpoint. The black color is only produced by a reducing atmosphere; the oxidizing fire will always give rise to a yellowish color. The old red Böttcher porcelain obtained its color from the high percentage of ferric oxide, and was fired under oxidizing conditions. In the reducing fire it would have become black. The Chinese porcelain often contains 2.5 per cent of ferric oxide, but does not become black in the reducing fire, but bluish green, while but 0.1 per cent of ferric oxide is sufficient to render porcelain unsalable on account of the gray color produced. How to account for this is easily seen. In the one case it is present as an iron silicate, while in the other it is free ferric oxide, and, according to the state in which it is present in clays, they will be colored green or gray in the reducing fire. Free ferric oxide is reduced to metallic iron at a low temperature (the statements in the literature vary from 400° to 700° C.), while this is not true of the silicates. The Chinese porcelain, which contains such a high percentage of iron, shows this fact by assuming in the places not covered with glaze, when exposed in the muffle kiln, an intense brownish yellow color. This is an oxidation from the ferrous to the ferric silicate. Every museum containing Chinese porcelain proves this. One clay may contain much iron, and will burn white or bluish green, while another clay which contains only very small quantities will burn to a gray.

In the manufacture of porcelain we cannot use the latter at all, even if the iron content is very small; they must be excluded if experiments show the production of the gray color. At the same time other clays which give a bluish or bluish green cast, though they contain more iron, are not rejected by the manufacturer. It is not correct to say that iron filings which are introduced in the body always color the latter black. They will be black only in the reducing fire; in the oxidizing fire, they assume a yellowish brown color.

When I speak of the manufacture of glass this is due to the fact that I have to make colored glasses for the compounding of colored glazes for porcelain and whiteware: this is part of my daily occupation; hence, I believe that I am competent to have opinions on this side also. I use for this purpose a kiln fired with gas, from which we can take correct fire-gas samples for analysis more readily than from the coke furnace usually employed. I have often had opportunity to melt colorless glasses together with iron oxide without any other coloring agent. When the glass was clear, free from sulphuric acid, which is not usually the case, and the ferric oxide was purified from sulphuric acid, it was found that the oxide dissolved without any evolution of gas, and in oxidizing conditions produced a yellow to red-brown color; in the reducing fire, a green to black glass. If one of the ingredients contains sulphuric acid, the solution of the ferric oxide goes on without gas evolution, giving a yellow glass in the oxidizing fire, but often with a separation of sulphates in the gall; in the reducing fire, however, evolving sulphurous acid, it melts to a green glass. This fact can be proved by not fusing the glass clear, but by stopping firing while it is still foaming. The presence of the sulphurous acid is detected, when we break the glass cake, by the odor. I can therefore not yield to the point that ferric oxide dissolves in the glass to form ferric-ferroso oxide with an evolution of oxygen. The yellow to reddish brown ferric oxide glazes which I have used for years are proofs of this argument. The Royal Porcelain Manufactory uses, for its yellow-brown glazes, ferric oxide without any other addition, without having very great trouble owing to the black or green coloration by reduction. It is only necessary to stop the reducing conditions of the fire at the right time.

The mention of the puddling process is not well chosen. It certainly is an oxidizing process. The slags produced in this way, however, are mixed with iron and carbon iron compounds, and protected from oxidation. The latter are very energetic reducing agents.

I have sent Professor Knapp, as proof of my arguments, small pieces made from a body to which ferric oxide was added, and glazes which are colored with ferric oxide and iron filings in quantities of 1, 5 and 10 per cent. These pieces are to prove that on oxidation porcelain will always be yellow, while in the reducing fire it will assume a white or bluish green color. A gray color will result from free ferric oxide only when the firing is done under reducing conditions. It is, therefore, necessary to show in analyses the percentage of ferric oxide as it is responsible for the color of the porcelain.

The Coloration of Porcelain and Glass in the Glost-Burn

ALBERT BLEININGER, B.SC., TRANSLATOR

The discussion on this topic, with the statement of Professor Seger in No. 34 of the *Chemiker Zeitung*, seems to deviate too much from the original premises. My first claim stated solely that in the porcelain kiln and the glass furnace, ferric oxide does not color yellow but green or gray. It was not intended to deny that bricks are usually brown or red and common pottery yellow, but it was the sense of the article to affirm that at temperatures at which hard porcelain, like the Chinese, is finished or plate or hollow glass is melted the possibility of yellow colors due to iron is removed, and only a green or grayish green can be produced.

As far as the porcelain is concerned, the above statement is based on an experience of ten years with a kiln of five furnaces which were fired with split pine wood. At the high temperature of even the beginning glost heat, the wood does not burn as in the ordinary furnace, but it is decomposed into wood gas as in distillation, leaving behind only about 10 per cent of coal and evolving a voluminous, intensely bright flame. It is always oxidizing, for wrought iron tools left in the kiln were found burnt up and even fused through three saggars. The temperature is so high that while metallic nickel still stands, cobalt is strongly volatilized. The pottery burnt in the kiln mentioned at first suffered severely from the black spots due to fine iron specks, but never has a single yellow-colored spot been seen; without exception they are found to be of a dark greenish color. On adding ferric oxide to the porcelain body in increasing quantities, the gray porcelain made mention of is obtained in the corresponding gradation of shades.

In the same establishment, in the same kiln, and same fire, fire-bricks are burnt beside the porcelain. The material used is a grog from broken saggars with raw saggar clay, very high in iron. The trial pieces drawn at the conclusion of the burn, cooled rapidly in the air, assumed an agreeable gray color. The bricks in the kiln, cooling slowly, possessed a brown color, resembling that of bread crust. Only the parts of the surface protected during the burn remained distinctly gray. The temperature of the brick burn approaching that of the glost burn colors the ferric oxide exclusively to a gray color. Only after the conclusion of the burn when the temperature has been lowered to a certain point is the gray of the bricks changed to a brown by the air drawing through the kiln, this color being restricted to the extreme outer surface. The fracture of the bricks is gray throughout the thickness excepting the extremely thin superficial coating. The bricks are not vitrified at all.

In burning common bricks and tiles, these products, owing to the lower temperature under normal conditions, assume (according to the content of iron) a yellow to reddish brown color. As soon, however, as any abnormal increase in temperature takes place up to the softening of the ware, giving rise to "blotching," the color at once changes to iron-gray. Before this rise in temperature the vitrifying bricks are, of course, reddish brown. In order to explain the change in color to gray, Professor Seger brings in at once "reducing influences" at the critical point, as *deus ex machina*, at a time when they are most unlikely to occur. The vitrification prevents the reappearance of the brown color by oxidation. As far as the glass is concerned, for several kinds of glass, a certain iron content and the color connected with it is considered harmless. This color is always green, never yellow. According to Professor Seger, the plate glass furnaces must have been under reducing conditions for centuries. The same might be said for cast mirrors; the slight iron content remaining never produces any other color but green with a more or less pronounced bluish tinge although enough oxygen is found in the furnace.

According to the conception of Professor Seger the phenomena in question involve a play of oxidation and reduction, a plus or minus of oxygen. This conception has taken such hold with him that it leaves no room for the thought that other factors might be active. Such a factor is indeed present, namely, temperature; it is not the reaction of the flame but primarily its temperature which influences the coloration by the iron. At the high temperature of the porcelain kilns and glass furnaces the ferric oxide will only produce a green color modified to gray under certain conditions; only at lower temperatures is it possible for yellow or brown colors to exist. The error of Professor Seger is based on overlooking the effect of temperature; if once this is acknowledged, all the phenomena are explained satisfactorily.

The following experiments will suffice to remove any doubts since they are based on practical work. At this laboratory a series of soda-lime glasses with an addition of from 3 to 6 per cent of ferric oxide was fused in a crucible and coke furnace with a strong chimney draft; all the glasses were of a deep bluish green color. The same thing was true of other batches containing metallic iron in place of ferric oxide. These also resulted in clear but somewhat more bluish green glasses. Fragments of these green glasses in a porcelain boat were placed in a porcelain tube across the coke furnace, at a white heat, and a stream of oxygen was slowly passed through the tube so that at the exit opening of the tube during the entire operation a glowing splinter was kindled to a flame. At a temperature at which the glaze of the porcelain boat was fused, in an atmosphere of pure oxygen, the glass trials remained in fusion for seventy-five minutes without being changed in color and showing not the slightest trace of a yellowish tinge.

Professor Seger was kind enough to send me samples of yellow porcelain colored by iron. Without knowing the conditions under which these were produced, little can be said concerning them. With several, the glaze is yellow or yellowish brown; on a small basin the coloring-matter is incorporated in the body, but the color is as much yellow as gray and, hence, proves nothing; a few samples were of Seger porcelain burnt at a low temperature. A third specimen was more interesting—a lid on which iron filings had been sprinkled: Each grain appears as a dark center surrounded by a dark yellowish spot. On igniting fragments of this lid with the iron filings in the porcelain tube mentioned above, in the coke furnace for seventy-five minutes, together with the pieces of green glass in a stream of oxygen, the yellow spots around the iron specks were changed to grass-green.

From the material of facts available the truth becomes at once evident: At high temperatures above a certain temperature (porcelain glost burn, glass furnace) the iron invariably colors only green or grayish green whether the firing conditions be oxidizing or reducing; this is true even in an atmosphere of pure oxygen. The color is solely a function of the temperature.

It is by no means my intention to dispute the effects of oxidation and reduction, but these should be restricted to their natural proper temperature limits. It is only the injudicious generalization of this effect which we dispute. In the hope of an agreement on the basis of my statements, I consider the discussion ready to be closed. PROF. KNAPP.

In No. 41 of the *Chemiker Zeitung*, Professor Knapp publishes another article on this topic but to which I have been unable to reply, owing to illness. In it he says that I have left the original point of dispute. I must accuse Professor Knapp of this. He claimed originally that the iron content of the kaolin has nothing to do with the color of the porcelain; that ferric oxide in the porcelain always produces a gray or black body and that the color is due to the presence of alkaline sulphides. I have protested against this and Professor Knapp has not proved his point to my satisfaction by going into the processes of the glass industry; in fact, I am more convinced than ever of the truth of my views for he has furnished no proofs for his assertions; and even if I did accept Professor Knapp's latest statement, that the color of porcelain is solely a function of the high temperature, and the oxidation and reduction processes could be neglected, it should be realized that the porcelain is not like glass taken from the kiln in the white-hot condition, but that it cools slowly, this cooling taking place in a strongly oxidizing atmosphere. If the ferrous silicate formed in burning changes to ferric silicate, as we have seen in the case of the fire-bricks which he burnt at Nymphenburg and which he describes, this does not mean that the color effects of the iron at lower temperatures should be neglected. The reactions at higher temperatures should not be used to explain all cases. The views offered by me explain the color phenomena readily and completely while those of Knapp include a series of hypotheses which must be proved before they can be accepted.

PROF. DR. H. SEGER.

The Hard-Fire Red of European Porcelain

ALBERT BLEININGER, B.SC., TRANSLATOR

The *Sprechsaal*, No. 37, 1883, publishes the following article:

In the conclusion of the article on the latest work of the Royal Porcelain Manufactory at Berlin, in No. 33 of this journal, the statement is made that the most important achievement of the past year was the production of the Chinese-red which, until now, has only been prepared at Nankin. The article continues to mention a few, usually very defective, pieces produced in European potteries, and finishes up by saying that the production of these pieces was more in the nature of a fortunate accident than the result of systematic experimenting with the aid of technical chemistry. This statement is to be corrected.

The editor of the *Sprechsaal* took occasion to call attention to an article which I published in the *Thonindustrie Zeitung* in 1880, Nos. 13 and 14, on the red and flashed red of the Chinese, a hard-fire enamel for feldspar porcelain recently made by Th. Deck, of Paris. In this little essay, the results of special studies at Paris, the experiments of L. A. Salvétat from 1848 on, are mentioned, and from the publications of this excellent technical chemist, observations, rules, and analyses are given, and the specimens of the red porcelains made by Salvétat described.

The second and main part of the essay consists in a description of the fine work of Th. Deck, of Paris, the separate kinds and color shades of his red porcelains. On my last visit at Deck's in the fall of 1882, I saw an entire collection of such porcelains in all shades of the hard-fire red from the brightest, glossy transparent cherry-red to the darkest, matt, and opaque blood-color, and in addition long-necked, small bottles in bright red, showing many aventurine — and gold-like, shining particles, pieces truly grand and magnificent.

But another place where the porcelain hard-fire red is produced must be named, namely, Krummnussbaum in Lower Austria, where the well-known technical chemist, A. Buenzli, is active. Nearly two years ago at the Leipzig fair he appeared to the surprise of everybody with a large assortment of decorative porcelain which was decorated exclusively with hard-fire colors. The range of these colors is quite extensive, the decoration of the pottery, very plain in shape, is mostly oriental in taste and usually the colored ornamentation is supplemented by gold cloisonné (muffle). Perhaps a substitute will be found for the muffle gold, be it a plastic or colored application, which, for unity's sake, should be, hard-fire work. Of special interest among the Buenzli hard-fire colors is the changing gray. This color appears dove-gray in daytime, sometimes with a reddish sheen; in artificial light this color is changed to a strong blood-red. This interesting assortment of porcelain was completed by red porcelain: vases, lamp bodies, bottles, and pails in brilliant cuprous oxide red, light and dark, flashed and in other varieties. These porcelains cannot be cheap in the sense of staple ware, yet the manufacturer endeavors to reduce the cost sufficiently for fair and export purposes.

Thus three ceramists are named, beside the Royal Porcelain Manufactory at Berlin, who have produced the Chinese hard-fire red; all of these three have shown their results publicly before the Royal Porcelain Manufactory. The achievements of this establishment are, without question, to be highly esteemed; nobody desires to detract from them, but the statement quoted above does not apply to the three ceramists named.

ALEX. SCHMIDT.

Reply

Professor Alex. Schmidt endeavors to prove in the above article that the Chinese-red was made in Europe on a commercial scale before the Royal Porcelain Manufactory produced it. He mentions first the Salvétat experiments which, according to him, date from the year 1848. I do not doubt that such a fine chemist as Salvétat went to work systematically, but whether he attained the desired results is another question. The experiments of Salvétat are described in "Salvétat, Decoration and Enamelling," translated into German by the Imperial Austrian Museum, pages 24 and 26.

The analyses quoted check tolerably well with mine, which are as follows:

	Per cent.
Silica,	71.07
Alumina,	3.24
Ferric oxide,	1.40
Calcium oxide,	9.20
Magnesia,	1.75
Lead oxide,	4.15
Copper oxide,	0.92
Potash,	8.11
Tin oxide,	trace
	99.84

The interpretation of the analysis is, however, given wrongly by Salvétat. He gives the composition of the glaze as being:

	Per cent.
Feldspar,	50.00
Chalk,	12.00
Copper oxide,	6.00
Sand from Aumont,	38.00

If matters were as simple as this the high price of red porcelain could not be explained; it would be an easy matter to make the red for it is not difficult to produce reducing kiln conditions. Salvétat says that he has taken the content of copper oxide so high because copper is volatilized at a high temperature. According to my experience, this is never the case; copper, as cupric oxide, spreads and volatilizes strongly, and penetrates even the body. As cuprous oxide I have never observed any evidence of volatilization. I use for transparent red 0.05 to 0.25, for opaque red 0.50 to 1.00 per cent of cupric oxide. More than this amount is injurious and renders the burning more difficult. Salvétat also explains that the ware must be burnt in the reducing kiln condition, which is difficult to maintain. This also is erroneous. The porcelain must be finished in the oxidizing flame if it is to assume a fine red color, though the proper time for doing this is not readily determined. Even on decreasing the copper content and firing finally in oxidizing fire conditions, no results are obtained with the Salvétat formula. The glaze if it does not become gray or black, which is usually the case, assumes a copper color only in places, and never attains the magnificent red color of the Chinese ware. If it had been possible to obtain constant results according to Salvétat, Sèvres would not have hesitated to show this ware at the expositions.

The conditions are different with Th. Deck, of Paris. Deck possesses, since 1880, about 20, mostly smaller, pieces showing this red color, but these are not salable—not as Mr. Schmidt says: "Th. Deck manufactures this ware regularly as far as the sale of these naturally expensive wares will permit it, and his prices are higher than those for the Berlin products." Why this high price? It cannot be due to the material used; it must be owing to the fact that out of 50 or even 100 pieces only one shows the desired effect, or entire burns may not produce a single red piece. Is this not a manufacture based on accident?

It is not surprising that Th. Deck possesses pieces in all variations. Any one acquainted with the manufacture will realize that hardly ever, even two pieces of the same color come from the kiln. This is likewise true with us.

As to A. Buenzli it cannot be said that he did not proceed systematically, but whether he has attained his object is likewise doubtful. The fair of 1881 showed about three pieces of Chinese-red; the one of 1882 about a dozen. Is it not justifiable to assume that the production of these pieces is due to a fortunate accident though a definite aim may have been followed by the makers? Is this to be called a manufacture on a commercial basis? What the present state of this decoration is with Buenzli I do not know; but this much is certain, the Royal Porcelain Manufactory produced the Chinese-red ware on a commercial basis which cannot be said of any other pottery. This means not that a thing can be done several times but that it can always be done.

Conditions are entirely different at the Royal Porcelain Factory. Here not an occasional piece is produced but a regular manufacture has been established. Burns are made in which a kiln holding 5 cubic meters is filled with red ware and without an appreciable loss. I shall be glad to prove this to the satisfaction of Professor Schmidt. Thus it is possible to produce the pieces at prices which do not differ greatly from those of other colored porcelain. It is obvious that pieces of special beauty of shade, which also with us are dependent on fortunate conditions, bring higher prices. For the other red porcelain the prices are determined by the similar Chinese pottery, or by the muffle decoration in gold and enamels which is never applied on the Chinese ware. Before the Royal Porcelain Manufactory no pottery has made this ware on a commercial basis, for the fact that somebody has obtained a few pieces does not make it possible to produce 100 or 1,000 pieces. It is possible that a person who has systematically striven to attain the result may have met with a fortunate accident. Not his intention but the success is accidental, and hence the statement, "the production of those pieces is due more to a fortunate accident than to the systematic results of technical chemistry," is justified.

D. UNCOMPLETED WORK AND COMMUNICATIONS FROM THE RECORDS OF THE ROYAL PORCELAIN MANUFACTORY.

Communications Concerning the Testing of Brick-Clays by Members of the German Association of Clayware Manufacturers

PROFESSOR EDWARD ORTON, JR., TRANSLATOR

The first suggestion for the collection of the following statistical matter, and the investigation growing out of it, was made by our associate, Mr. Lietzmann, and was supported with such interest by those members who were in position to furnish contributions, that we believe this to have been the cause of the publication of the materials thus collected, although we are well aware ourselves that the work has not yet been carried to a point where a complete solution of the question, as originally contemplated, has been reached.

Nevertheless the matter, as far as completed, furnishes sufficient matter of interest for all owners of brickyards and brick machines that its publication seems desirable, and it will afford a valuable guide and help in furnishing comparisons of the properties of their materials with those used in other places.

The following tables should not only show the possibility of making a comparison of the efficiency and power consumption of the machine systems which predominate in Germany, but also of seeking out the relations which exist between the physical properties of the clays which come into consideration in the homogenizing of the clay, and the molding of the green brick, and between the results obtained in practice. For this purpose, numercial expressions for describing the properties of the materials must be used, which are to replace the subjective estimation and valuation; how far this has been carried out may be found from the explanation of the separate columns which contain the scientific matter of the tables.

Those parts of the tables, which contain the data generally furnished us by proprietors of brickyards, concerning their practical results, require no further explanation, but it seems to be in place to set forth the fundamental principles which have directed us in carrying out the investigation, explaining the value of the numerical expressions.

1. The water content, with which the clays are treated in preparation and molding, compared with the clay content of the brick earths, controls, on the one hand, the degree of pliancy and plasticity which the clay attains, and on the other, it gives a measure for the quantity of water to be evaporated during the drying period, and therefore the amount of time in which it should be completed. In comparing the water content of freshly molded bricks, one will observe that in general the fat clays, or those which contain a large quantity of clay substance (after deduction of the carbonate of lime which is present in many cases in a fineness approaching that of the clay substance) are generally worked with a perceptibly higher water content than the clays high in fine sand or silt. It must be borne in mind that this increased content of water does not necessarily mean a greater softness of the body but these differences are to be sought solely in the properties of the clay. It is found that the brick-clays highest in finest clay substance require much more water in order to assume a certain degree of softness. Since the consistency necessary for all machines which squeeze out the clay in a bar is about the same, and since in this plastic condition a slight increase in water may cause great fluctuations in softness, it is almost possible to assume that the amount of water necessary to

give to two clays a certain degree of consistency stands in a simple ratio to the content of real clay substance.

In estimating the time of drying as well as the shrinkage of the bricks on drying, the knowledge of the content of water in the bricks seems of special importance because the amount of water necessary to make clay plastic determines the size and arrangement of the dryers.

2. Closely related to the water content of the clay is the *shrinkage in drying* which governs the size of the dies on the machines as well as the greater or smaller sensibility of the material on rapid drying. It is seen that the shrinkage on drying does not stand in a simple ratio to the "fatness" of the material but that shrinkage is greater with a certain addition of fine sand in spite of a lower water content of the body than with a material consisting of the very finest clayey constituents. To this fact is due the great tenderness of some lean and short clays.

3. Similarly the figures expressing the amounts of *water expelled in water-smoking* stand in an intimate relation to the phenomena appearing in drying as well as in water-smoking. As is known, finely powdered bodies are more or less hygroscopic, *i. e.*, they possess the property of absorbing water-vapor from the air which condenses in the pores. Clay substance exhibits this power to a high degree, while other finely pulverized substances, like quartz dust or chalk, are not able to hold back quantities of water worth mentioning. This property of retaining water brings the clays into a continual struggle with the water-removing properties of the atmosphere, and as a consequence, the strongly hygroscopic bodies are less easily inclined to give up their water by evaporation than those of less hygroscopic character. The absolute quantity of residual water held by clay at ordinary temperatures becomes of special importance in the water-smoking of the bricks, because even with perfectly air-dried bricks the danger of water-smoking increases in proportion as the quantity of water, which can be removed only by an elevation of the temperature, becomes greater. The difficulties are hence the greater, the greater the affinity of the clay, as expressed numerically in the table, for taking up water from

saturated air, since it expands in consequence of this absorption of water, and calls for those phenomena which we collect under the term "water-smoking."

The column of *loss on ignition* gives those losses of weight, which comprise the loss of water, that air-dry bricks suffer in burning, *i. e.*, the expulsion of hygroscopic and chemically combined water, carbonic acid, and the destruction of organic matter, and which increases the porosity unless some shrinkage has taken place in the soft burn.

The further four columns *v* comprise the results of the *physical analysis*, and indicate the main and most evident character of the clay. It would be possible to classify the clays according to whether separate well-defined constituents predominate. In this way the clays could be classified into coarse sandy, fine sandy, silty, fat materials, or if two constituents predominate over the others into coarse and fine sandy, coarse sandy and silty, coarse sandy and clayey, fine sandy and silty materials. A strict classification can, however, not be carried out since the relative effects of the separate non-plastic substances on the modification of the properties possessed by the clay substance cannot be determined easily. The constituent known as clay substance, owing to its fineness, often shows a varying behavior so that in estimating the properties of a clay not only the mechanical analysis but also the values in the other columns must be taken into consideration. The separate constituents of the clay are designated by names which are already familiar to the practical men. Coarse sand includes all those detrital minerals whose size of grain permits them to be recognized by the unaided eye, and which do not require the sense of touch to designate them as sand; this ingredient of almost all brick-clays comprises all materials down to a minimum diameter of 0.2 mm. In the fine sand, whose diameter of grain has been taken from 0.2 mm. to 0.04 mm., the sense of touch must be brought in as aid, in order to recognize it as sand. The dust, sand and silt already possess one of the characteristic properties of clays, in the fact that they show a mild degree of plasticity when in a moist condition, but after drying they do not furnish a hard, firmly cohering body as the latter does, but change into a scarcely cohering dusty powder. This designation includes all fine mineral detritus with a diameter of grain from 0.04 mm. to 0.01 mm. All of the finest portion whose further subdivision by washing processes seems no longer practicable is designated as clay substance, and includes all particles from a diameter of 0.01 mm. down to infinite fineness. While this series of non-plastic materials does not show the properties of clay, these properties do occur in the clay substance in the most pronounced degree; it cannot therefore be said that these properties reside only in clay substance as chemically defined, but the latter consists often of extremely fine mineral particles which are not plastic in the strictest sense but which cannot be separated from the clay substance mechanically. In those clays in which the calcium carbonate is contained in the finely divided state, which in itself does not possess the least degree of plasticity even in the state of finest division, the clay substance can be separated chemically, and this is shown by the quantities of calcium carbonate in the clay substance given in column A. The column A thus gives a correction in the mechanical analysis for the calcareous materials since the calculated amount of calcium carbonate is deducted from the clay substance and is added to the silt, to which it belongs as finest non-plastic material.

The mechanical analysis not only discloses the proportions in which the clay substance and the different sizes of non-plastic matter are found in the clay, but it permits of an approximate study of the separate constituents. In the coarse sand the mineralogical constituents as well as the injurious accessory ingredients can be determined more easily than in the clay itself.

The presence of gypsum crystals, lime nodules, iron pyritic concretions, the cementing together or hardening of the clay body by silicious, calcareous or ferruginous infiltrations can be easily recognized through the microscope or by chemical means, while these easily escape recognition in the clay body itself. In the fine sands down to the silt, we can recognize whether they consist of mineral detritus arising simply from mechanical processes, or whether they have already experienced a more or less severe chemical attack by weathering, or finally whether they have originated from the cementing together or hardening of the clay substance. In the first case, the fine sand and the silty ingredients show no shrinkage on drying from the moist condition; in the last two cases they show shrinkage and a strong tendency to crack, usually in a considerably greater degree than pure clay substance, though without attaining any firm cohesion. According to previous observations, this property of the fine sand and silty ingredients seems in close correspondence with the great sensitiveness which many brick clays show to air currents and quick drying; at least, all brick materials which are especially tender in drying show this property in their fine non-plastic materials.

Among the materials occurring as non-plastic in the finest state of division, beside the detritus of silicate rocks, calcium carbonate plays the most prominent part on account of the commonness of its occurrence, as well as its influence on the quality of the brick-clays. It occurs partly as an amorphous deposit from the water in which the brick-clays have their origin, partly from the microscopically small remains of infusoriae.

In column *s* the quantity of this lime is set forth; in column *t*, that amount of lime which equals clay in fineness of grain. Column *e* estimates the bonding power of the clays by Bischof's scale; the numbers given there mean the quantity of fine quartz powder which one part of the brick-clay is able to bind together, without dusting off when rubbed on the ball of the hand, and gives a measure of the strength which the brick-clays show after drying and also after burning. Column *v* contains short statements concerning the exterior properties of the intimately admixed ingredients of the brick-clays; the last column, *w*, offers data on the bricks produced and the power expended. It may here be remarked that the figures given cover the number of bricks produced in one hour per horse-power, and that when a maximum and minimum is given in the reports of the brickyard proprietors for the size of their output, the mean is taken in this calculation.

One may perhaps assume that in those cases in which material was tested and placed in comparison with the results of practice, the adoption of one or the other machine system is not entirely accidental, but is to be construed as the result of a partly instinctive, partly premeditated selection. Practical experience has usually been the guide.

One who proceeds to procure a machine, does not inform himself only as to its cost and capacity; he compares also the materials which are used in other places with his own and, according to the information which is given him by fellow manufacturers concerning other machines known to them, he forms a judgment as to which will be the most suitable for his conditions. In any case, it frequently happens that mistakes in reference to the installation and still oftener in regard to the manipulation of the machines are made, and that a smaller capacity of the machine than was expected is not to be ascribed to the machine itself or to the circumstance that it is not properly chosen for the material, but that other reasons are at the bottom of its failure. If one has bought a machine, he does his best, in spite of the original errors, to improve the qualitative or quantitative performance of the machine, before he decides to remove it and to replace it with another.

Though no conclusion can be reached in any given case from the performance of a machine, as to whether another system is to be preferred, since a whole multitude of unknown or difficultly estimated influences are involved, conclusions can be drawn in a great number of cases, like those contained in the table above described, which have at least a probability of approximating the truth.

If we set aside all machines which require a small expenditure of power being worked by hand-power, or by means of which products are made which do not permit of accurate comparison of performance, or which are not sufficiently defined to bring them into one or other of the various systems, the above figures will permit us only to make comparisons between the systems which we will designate as the Sachsenberg, the Hertel, the Schlickeysen system, and the soft-mud machines.

At the first glance, one can see from the tables that the production, calculated on the unit power consumption of horsepower per hour, is very variable. This variation stands in some relation to the greater or less degree of softness of the clay. In fact, the clays which are worked by the Hertel system seem the stiffest of all, to judge by the feeling; then follow those which are worked by the Sachsenberg, the Schlickeysen, and finally the soft-mud systems. In the last, the clay seems to be softer than in hand-molding.

As has been said before, the water content found by analysis is only significant of greater or less softness, when one compares clays which have a similar physical constitution, since the fatter clays must take up a greater quantity of water than the silty or sandy clays, in order to attain the same grade of plasticity. If, therefore, it appears as if the water content averages higher for the Sachsenberg than for the Schlickeysen machines, it must also be considered that the clay worked by the first averages considerably fatter, while in the latter the silt and fine sand preponderates.

The following little table which contains the arithmetical means of the preceding large table, shows clearly what variations the materials which are used with the different machines possess, and in what relation the physical properties of the clays stand to the power used in working.

No. of the separate determinations.	Name of the machine system.	Coarse sand.	Fine sand.	Dust sand.	Clay substance.	Water.	Capacity of the machine (full sized bricks) per horse-power per hour.
12	Sachsenberg	8.8	14.1	21.5	55.3	29.1	133
8	(*a*) "	7.9	13.3	20.5	58.2	—	152
11	Hertel	11.6	20.5	22.0	46.3	24.7	94
8	(*b*) "	11.2	22.1	23.9	42.4	—	117
5	Schlickeysen	13.8	23.2	26.7	36.2	23.0	165
2	Soft-mud	5.0	19.8	51.7	23.5	26.9	850

The standard size of German bricks is 9.8″x4.7″x2.6″.

The results marked (*a*) are the mean of those separate determinations in which the performance of the machine was relatively the most favorable, that is, in which the performance is better than the average of all of the determinations. One can see that in general the Sachsenberg machine works the fattest clay, and that the efficiency of this machine, which seems to be founded on its construction, increases with the fatness of clay, since the content of clay substance is higher in those cases where the performance is more favorable. In the Hertel machine, the reverse is seen, for here the performance becomes more favorable with the reduction of clay substance. The materials which are used with the Schlickeysen machine are characterized decidedly as silty, while the soft-mud machine works with the leanest and shortest materials which find use in brick manufacture.

The following tables contain these data in detail:

No.	System.	Owner of press.	Maker of machine.	No. presses.	Power consumed per hour in horse power.	Total power.	Capacity of press in ten hours.	No. workmen.		
								Wheeling clay.	Machine.	Removing bricks.
	a.	b.	c.	d.	e.	f.	g.		h.	
1	Sachsenberg.	Kuhnheim & Co., Freienwalde.	Sachsenberg Bros., Rosslau.	2	10	50	9,000	3	2	4
2	"	"	Bittrich, Angermuende.	1	—	—	—	—	—	—
3	"	A. Lauw, Bockhorn.	Sachsenberg Bros.	1	10	16	16,000	3	6	5 boys
4	"	W. Meisel, Muldenstein.	"	2	8 and 7	16	10–13,000 8–10,000	4 3	5 5	4 3
5	"	Hernsdorf Portland cement works.	"	1	6	25	6,000	2	5	2
6	"	F. Schlobach, Böhlitz.	"	2	12	?	14,000	4	4	4 boys
7	"	Karnagel & Oertel, Moeckern.	"	1	10	25	14,000	4	3	7
8	"	A. Rasch, Oeynhausen.	"	1	6	12	10,000	3	6	4 boys
9	"	R. Bohne, Schwiebus.	"	1	10–12	10–12	10,000	5–6	2–3	2–3
10	"	Greppin Works, Bitterfeld.	"	5	6–8	70	12–13,000 solid bricks.		9–15	
11	"	F. Hoffmann, Neckermünde.	Murray, London.	1	12	25	16,000	4	3	—
12	"	Marienburg Brickworks.	Sachsenberg Bros.	1	8	—	14,000	3	2	4
13	"	Gotschling, Orlowa.	"	1	6	6	10,000	3	4	4

No.	System. *a.*	Owner of press. *b.*	Maker of machine. *c.*	No. presses. *d.*	Power consumed per hour in horse-power. *e.*	Total power. *f.*	Capacity of press in ten hours. *g.*	No. workmen. Wheeling clay.	No. workmen. Machine. *h.*	No. workmen. Removing bricks.
14	Sachsenberg.	Count Dohna, Mallmütz.	Sachsenberg Bros.	1	8	—	8,000	3	2	4
15	"	v. Oettinger, Kalkuhnen.	"	3	6–7	20	10,000		15	
16	Hertel.	Wienerberg, Brickworks.	Hertel & Co., Nienburg, Hurz, Leobersdorf.	4 6	10	100	15,000	4	3	4
17	"	Schmelzer, Helmstaedt.	Röhrig & König, Magdeburg.	1	6	6	8–10,000	2	2 and 1 boy.	3
18	"	Phil. Holzmann, Frankfurt.	"	2	9	40	10–12,000	5	3	4
19	"	D. Peters, Grevenhorst.	Hertel & Co., Nienburg.	2	20	40	22,000	4	4	4
20	"	Buechting&Schimmler, Osterode.	Röhrig & König. Magdeburg.	1	12	12	7,700	3	2	4 and 1 boy.
21	"	Bethmann-Hollweg Hohenfinow.	Hertel & Co.,	1	10	40	4–4,500 hollow bricks.	2	1 and 2 girls.	4 girls.
22	"	H. Meisel, Muldenstein.	Röhrig & Co., Magdeburg.	1	10–12	18	10–12,000	4	4	4
23	"	F. Niemann, Bleckendorf.	Hertel & Co.,	1	12	—	10–12,000	4	2	4
24	"	E. Saelzer, Eisenach.	Röhrig & Co.,	1	6–7	—	6–7 or 5500 hollow bricks.	1 elev.	2 and 1 boy.	4 women.
25	"	Rochow, Rekahne.	Hertel & Co.,	1	16	18	10,000	3	1	2
26	"	Förster, Magdeburg.	"	1	12	—	12,000	3	2	3
27	"	Soc. des mat. d construc., Neufchâtel.	"	1	12	—	12,000	3	3 boys.	4 boys.

No.	System. a.	Owner of press. b.	Maker of machine. c.	No. presses. d.	Power consumed per hour in horse-power. e.	Total power. f.	Capacity of press in ten hours. g.	No. workmen.		
								Wheeling clay.	Machine. h.	Removing bricks.
28	Hertel.	Siegersdorf Works.	Röhrig & König, Magdeburg.	3	12	40	10,000	3	2 and 2 women.	8 girls.
29	Schlickeysen.	Victoria Brick-works, Eidelstedt.	H. Scharffenberg, Pinneberg.	1	8 incl. rollers.	24	10,000 face-bricks.	3	5	2
30	"	Ende & Böckmann, Schiffsmühle.	Hartmann, Berlin.	2	6–7 incl. rollers.	15	12,000	3	2	3 and 1 boy.
31	"	Ascher, Stuttgarten.	"	1	8	10	14–16,000	6 and 2 boys.	4 girls.	4–12 boys.
32	"	J. Helder, Dockum.	Schlueter & Maybaum, Berlin.	1	11	11	22,000	5	6 boys.	6
33	"	Ephraim, Posen.	C. Schlickeysen, Berlin.	1	—	—	—	—	—	—
34	"	Cochius, Heinrichsfelde.	"	1	—	—	—	—	—	—
35	Horizontal wooden pug mill.	Beck, Tarnborg.	?	2	?	6	11–12,500	3	2	3
36	Canadian press.	W. Huyssen, Essen.	Bawden & Co., London.	1	1	—	9,000	2	1 girl 1 boy.	4
37	Winn & Mytinger.	Löhnhold Bros., Rödelheim.	Snider Bros., Williamsport, U. S. A.	2	5	25	40,000	6	3	8
38	Whitehead.	Wienerberg Brick-works.	Salni Foundry, Vienna.	3	1	—	2,000 hollow or roofing-tiles.	?	2	?
39	"	Labyszyn Brick-works.	Cegielski, Posen.	1	2	—	1,200 3″ pipes.	1	3	1
40	"	A. Schaaf, Planena.	Labahn, Greifswald.	1			2,000 hollow bricks.	1	3	2 boys.
41	"	J. Schwantes, Slonavy.	Moegelin, Posen.	1	2	—	15,000 (?) 2″ pipes.	—	2	

No.	System. a.	Owner of press. b.	Maker of machine. c.	No. presses. d.	Power consumed per hour in horse-power. e.	Total power. f.	Capacity of press in ten hours. g.	No. workmen. Wheeling clay.	No. workmen. Machine. h.	No. workmen. Removing bricks.
42	Whitehead.	A. Rasch, Oeynhausen.	Labahn, Greifswalde.	3	1	—	1,000 face-bricks.		2 1 boy.	
43	"	C. Hecht, Newhof.	W. Bauer, Greifswalde.	3	2	—	1,200 bricks or 4,000—$1^{1}/_{8}''$ pipes.	—	2 girls.	1 boy.
44	"	Société des mat. de construction, Neufchâtel.	Hertel & Co.	2	1	—	1,000 bricks.	1	1	2
45	"	Siegersdorf Works, Siegersdorf.	Labahn, Greifsw.	1	2	—	2,000 pipes 34 mm	1	2	2 boys.
46	Clayton & Son.	"	Clayton & Son, London.	1	2	—	150 pipes 234 mm. socket.	2	2	2
47	?	Schmelzer, Helmstaedt.	Krull, Helmstaedt.	1	1	—	8,000 pipes $1^{1}/_{4}''$.	3	2	3
48	?	Beck, Tarnborg.	Heegard, Frederik Work.	1	?	6	12,000 pipes $1^{1}/_{4}''$.		2	
49	E. Laies.	A. Rasch, Oeynhausen.	E. Laeis, Trier.	2	1	—	1,200 roofing-tiles.		4 men 2 boys.	
50	Schmerber.	Schmelzer, Helmstaedt.	Schmerber Bros., Tagolsheim.	1	1	—	1,000 roofing-tiles.		3 men 1 boy.	
51	"	Siegersdorf Works.	Röhrig & König, Madgeburg.	1	1	—	7–8,000 roofing-tiles.			
52	?	Société des mat. de construction, Neufchâtel.	Sulzer, Winterthur.	1	3	—	3,000 roofing-tiles.	3	4 men 2 boys. 1	6 boys 1 boy.

No.	Drying arrangement. *i.*	Average time of drying in days. *k.*	Breakage. *l.* Per cent.	Addition of sand. *m.* Per cent.	Total content of water in 100 parts of dry clay. *n.* Per cent.	Linear shrinkage in drying. *o.* Per cent.	Water expelled in water-smoking. *p.* Per cent.	Loss on ignition. *qu.* Per cent.
1	Racks.	30	5	1/4	43.3	9.4	5.3	11.7
2	—	—	—	—	—	—	—	—
3	Sheds, 4 stories high.	21	1/3	0	33.4	6.5	4.0	5.3
4	Racks in sheds.	14–28	2	0	27.3	6.1	2.8	6.1
5	"	28	Small, in spring up to 25 per cent.	1/5	25.2	7.9	3.5	8.0
6	Hacks in sheds.	20–28	0	0	31.5	7.9	3.8	4.7
7	Sheds, racks and hacks.	16	1	0	30.7	8.0	3.9	5.8
8	"	10	2	0	22.1	6.2	2.7	5.3
9	"	14–21	1–2	1/5–1/6	21.9	6.4	2.6	11.3
10	Racks and hacks in summer, heated space, for 20,000 daily in winter.	8–12	2–5	1/20–1/10	—	—	6.2	9.4
11	Racks in sheds and hacks in the kiln house.	14	1	0	26.2	7.0	2.9	6.1
12	Racks.	14–21	2	0	34.5	11.5	4.8	5.1
13	Sheds without racks.	14	3	0	—	—	—	5.9
14	"	14	1	0	23.2	6.0	2.6	—
15	Open sheds.	14	1/2	0	—	—	—	—
16	Hacks in shed, 6 bricks high.	16	3	0	—	—	2.7	10.9
17	Sheds with removable sides, and racks.	14	2	1/6	23.6	6.6	4.3	5.9
18	Racks with movable laths.	21	3	0	22.3	6.7	3.6	4.8
19	Racks.	20	3	0	24.3	7.7	3.7	3.8

No.	Drying arrangement. i.	Average time of drying in days. k.	Breakage. l. Per cent.	Addition of sand. m. Per cent.	Total content of water in 100 parts of dry clay. n. Per cent.	Linear shrinkage on drying. o. Per cent.	Water expelled in water-smoking. p. Per cent.	Loss on ignition. qu. Per cent.
20	Racks in sheds.	21	5.5	0	—	—	2.1	2.6
21	"	21	2	0	23.4	6.8	4.2	8.6
22	Open sheds and open drying.	14-28	—	0	27.3	6.1	2.8	6.1
23	Racks.	21	8	0	23.8	7.7	—	6.8
24	Racks in sheds.	14-21	1	0	21.1	5.0	2.5	2.9
25	2 floors above continuous kiln and sheds with open sides.	20-25	2	$^1/_3$	22.1	6.6	3.5	8.7
26	$^2/_5$ in racks, $^3/_5$ in hacks in closed sheds.	20-25	3	$^1/_8$	28.5	8.0	6.5	6.6
27	Drying floors.	14	6	—	29.8	5.5	2.1	15.4
28	Sheds and racks in summer, heated space in winter.	21	1	$^1/_4$	28.2	4.5	5.0	5.0
29	Racks on 2 floors above gas-kiln.	—	1	0	20.4	5.8	—	9.4
30	Racks.	21	2		23.8	8.0	—	2.8
31	Open-air drying, 4 bricks high.	9	2	0	21.0	5.9	2.0	8.8
32	Racks in sheds.	28-35	0	$^1/_6$ sand $^1/_6$ lime.	21.0	4.8	2.2	10.0
33	———	—	—	0	29.0	7.7	4.2	6.8
34	———	—	—	—	32.54	8.7	4.2	11.5
35	Open air.	21	10.0	—	21.2	5.4	1.8	—
36	Open air on boards.	12	4	$^1/_{20}$	27.9	7.4	2.3	—
37	Drying floor in winter, open air in summer.	In winter 24 hours, in summer 8 days.	1	— —	31.1 27.2	10.1 5.2	1.6 0.6	31.4 7.6
38	Racks in sheds.	14	3 hollow bricks; 5 roofing-tiles.	0	34.4	9.0	3.1	9.6

No.	Drying arrangement.	*k.* Average time of drying in clay.	Breakage. *l.* Per cent.	Addition of sand. *m.* Per cent.	Total content of water in 100 parts of dry clay. *n.* Per cent.	Linear shrinkage in drying *o.* Per cent.	Water expelled in water-smoking. *p.* Per cent.	Loss on ignition. *qu.* Per cent.
39	Shed floors.	14	1	0	27.0	8.4	2.3	13.1
40	Racks to 5 rods from machine.	16	3	0	32.5	9.2	3.4	5.8
41	Racks.	16-20	5	1/5	29.9	8.4	4.6	5.0
42	Racks in sheds and heated spaces.	8	1	0	—	—	—	—
43	Racks in sheds.	15-20	2-4	0	21.9	6.3	1.9	12.9
44	Racks.	10	2	—	—	—	—	—
45	Racks above continuous kiln.	21	6	1/3	28.2	4.5	5.0	5.0
46	———	28	2	1/2 grog.	—	—	—	—
47	Racks.	8	4	0	—	—	—	—
48	Racks under kiln roof and on top of kiln.	21	10	1/20	—	—	—	—
49	Fixed and movable racks.	10	1	—	—	—	—	—
50	Racks.	8	1	—	—	—	—	—
51	Racks above the continuous kiln.	14-21	5	—	—	—	—	—
52	Racks.	8	10	—	—	—	—	—

No.	Physical analysis. r.				Calcium carbonate.					
	Coarse sand over 0.2 mm. diam. Per ct.	Fine sand 0.04–0.02 mm. diam. Per ct.	Dust sand, and silt 0.01–0.04 mm. diam. Per ct.	Clay substance below 0.01 mm. Per ct.	s. In clay aggregate. Per ct.	t. In clay substance. Per ct.	u. Bonding power. Per ct.	Properties of non-plastic materials. v.	Capacity of press per hour and horse-power. w.	Remarks. x.
1	1.00	20.2	27.6	51.2	13.6	15.1	4.0	Coarse sand : contains lime and gypsum ; fine sand cracks a great deal.	90	
2	—	—	—	—	—	—	—		—	
3	3.1	11.6	38.1	47.2	0	0	3–4	Coarse sand : quartz and iron concretions ; fine sand, yellow, does not crack.	160	Material for paving brick ; Oldenburg size.
4	6.0	21.0	20.9	52.1	0	0	3	Coarse sand : quartz, feldspar, lignite fragments ; fine sand cracks.	144	
5	—	—	—	—	—	—	—		129	
6	22.6	14.3	20.2	42.9	11.8	15.8	3	Coarse sand : quartz and small lime grains ; finer sand does not crack.	100	
7	14.3	12.1	17.6	55.7	0	0	4	Coarse sand : quartz, mica, iron concretions.	117	
8	10.2	14.0	17.0	58.7	0	0	3–4	Coarse sand : quartz and slate fragments.	140	
9	13.5	17.7	21.2	47.6	3.5	2.4	3	Coarse sand : quartz, feldspar, small lime grains ; fine sand does not crack.	166	
10	6.8	19.6	25.5	48.1	16.9	21.1	3	Coarse sand : quartz, flint, coal fragments, few lime grains ; fine sand does not crack.	91	
11	0	5.4	11.1	83.5	0	0	6	Clay nodules : fine sand cracks strongly.	142	

No.	Physical analysis. r.				Calcium carbonate.					
	Coarse sand over 0.2 mm. diam. Per ct.	Fine sand 0.04–0.02 mm. diam. Per ct.	Dust sand, and silt 0.01–0.04 mm. diam. Per ct.	Clay substance below 0.01 mm. Per ct.	s. In clay aggregate. Per ct.	t. In clay substance. Per ct.	u. Bonding power. Per ct.	Properties of non-plastic materials. v.	Capacity of press per hour and horse-power. w.	Remarks. x.
12	10.3	8.5	19.1	62.1	5.9	7.8	2–3	Coarse sand in excess: fine sands do not crack.	133	Machines correspond to the Sachsenberg system; cutter of the Murray patent.
13	4.4	12.9	27.8	54.9	0	0	4	Sands do not crack.	175	
14	—	—	—	—	—	—	—		166	
15	14.0	18.8	8.7	58.5	0	0	3–4	Sands are clear quartz grains.	100	
16	—	—	—	—	—	—	—		154	
17	2.0	16.0	14.4	37.5	16.0	13.2	2–3	Coarse sand: mostly quartz grains, lime concretions, and shells.	150	
18	6.2	44.6	24.2	24.8	14.2	12.11	2–3	Coarse sand: quartz, mica coal residue, cemented by calcium carbonate; fine sand does not crack.	150	
19	19.4	15.5	8.5	57.1	0	0	4–5	Coarse sand: quartz and feldspar grains, some iron concretions; fine sand does not crack.	122	Double rollers: for face-brick clay passes through press twice; once for hollow bricks.
20	24.3	16.4	15.8	43.4	2.2	3.1	3–4	Coarse sand: quartz and small lime concretions.	110	
21	1.5	12.2	50.3	36.0	0	0	0–1	Fine sands do not crack.	64	
22	2.4	17.8	30.0	49.9	11.8	14.8	3–4	Coarse sand: lime concretions, fine sand does not crack.	42	Hollow face-bricks.
23	6.0	21.0	20.9	52.1	0	0	3	Coarse sand: quartz, feldspar, and lignite, fine sand cracks.	100	
24	13.4	37.6	19.8	29.2	6.8	8.4	3	Coarse sand: quartz and different mineral detritus; fine sand cracks.	92	

No.	Physical analysis. r.				Calcium carbonate.					
	Coarse sand over 0.2 mm. diam.	Fine sand 0.04–0.02 mm. diam.	Dust, sand, and silt 0.01–0.04 mm. diam.	Clay substance below 0.01 mm.	s. In clay aggregate.	t. In clay substance.	u. Bonding power.	Properties of non-plastic materials. v.	Capacity of press per hour and horse-power. w.	Remarks. x.
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.			
25	6.4	32.0	26.9	34.7	0	0	1–2	Coarse sand: quartz, rock fragments; fine sand does not crack.	100	
26	17.6	22.7	11.6	48.1	8.2	12.1	3–4	Coarse sand: quartz and other detritus.	62	
27	24.6	11.8	9.5	54.1	trace	trace	5	Mostly quartz sand; does not crack.	100	
28	3.1	19.6	39.8	35.5	19.6	20.7	2–3	Coarse sand: quartz grains, roots, tufa and shell fragments.	100	
29	26.6	12.1	3.7	59.6	0	0	4	Coarse sand: mostly quartz, iron concretions, coal residue; fine cracking.	83	
30	21.4	24.3	21.8	32.5	16.0	12.1	2–3	Coarse sand: quartz and lime fragments; fine sand not cracking.	125	Yellow burning.
31	25.9	28.4	11.6	34.2	1.4	0.8	2–3		125	Red burning (bricks 23 cm. long).
32	3.0	18.0	30.1	38.9	12.4	7.7	2	Quartz, mica, lime, and shell residue.	185	
33	17.2	10.6	30.7	41.4	11.4	9.3	3	Quartz, sand, and small shell detritus.	188	
34	1.7	34.7	29.4	34.2	4.4	11.8	3–4	Coarse quartz grains, cementation by calcium carbonate.	200	
35	1.9	6.5	20.9	70.7	17.0	15.8	3–4	Fine sands crack.	—	
36	21.6	13.9	21.6	42.9	16.9	15.7	2	Fine sands crack.	—	
37	4.1	15.3	23.3	57.5	21.5	18.6	—	Coarse sand: quartz and lime fragments.	196	
38	3.8	21.5	49.7	25.0	0	0	0–1	White quartz fragments, hornblende, coal; fine sand does not crack.	900	
39	6.1	18.2	55.9	19.8	8.8	9.9	0–1	——	800	
40	0.5	15.9	36.7	46.9	10.0	13.9	4–5	Small shell fragments, quartz grains.	—	

No.	Physical analysis. r.				Calcium carbonate.					
	Coarse sand over 0.02 mm. diam. Per ct.	Fine sand 0.04–0.02 mm. diam. Per ct.	Dust sand, and silt 0.01–0.04 mm. diam. Per ct.	Clay substance below 0.01 mm. diam. Per ct.	s. In clay aggregate. Per ct.	t. In clay substance. Per ct.	u. Bonding power. Per ct.	Properties of non-plastic materials. v.	Capacity of press per hour and horse-power. w.	Remarks. x.
41	5.4	10.2	33.6	50.8	22.2	24.8	2–3	Quartz, feldspar grains, calcium carbonate as cement.	—	
42	8.9	20.0	29.4	35.6	trace	trace	2–3	Little quartz, usually ferruginous cementation, some shells.		
43	12.5	18.3	11.4	57.8	0	0	5–6	Fine sands consisting of clay nodules, cracking.		
44	—	—	—	—	—	—	—			
45	0.3	10.3	43.8	45.6	22.7	25.0	2–3	Quartz grains and small lime nodules, not cracking.		
46	—	—	—	—	—	—	—			
47	26.6	12.1	3.7	59.6	0	0	4	Mostly quartz, with iron concretions and coal residue.		
48	—	—	—	—	—	—	—			
49	—	—	—	—	—	—	—			
50	4.1	15.3	23.3	57.5	—	—	—	Quartz sand, small lime fragments, and fine sand, does not crack on drying.		
51	—	—	—	—	—	—	—			
52	—	—	—	—	—	—	—			
53	—	—	—	—	—	—	—			
54	—	—	—	—	—	—	—			

Results of an Inquiry Made by the German Society of Clayware, Lime and Cement Manufacturers, into the Fuel Consumption of the Different Kiln-Systems.

PROFESSOR EDWARD ORTON, JR., TRANSLATOR.

The committee has commissioned me to collect the circulars which we sent out in the preceding year (summer of 1882) in order to obtain from them the results of the inquiry. This was no light task, as the answers were not made uniformly. One used hektoliters and kilograms, another was calculated in bushels and pounds, and therefore the calculation of the data involved considerable work.

Among the circulars which have come in (about 50), there are several which lead to no result, because they have failed to determine the coal consumption in the kilns concerned. Those brickyards in which both continuous kilns and other kilns are working simultaneously, have unfortunately sent in most cases the results only for the continuous kilns, and the other kilns are therefore not well represented. In reference to the kilns, there have been received 58 useful returns. In total there were 70, but a number of these led to no results. I have calculated in this compilation the coal in kilograms per cubic meter of kiln space, because the different wares which are reported, as whiteware, chemical stoneware, bricks, roofing tile, etc., occupy very different volumes, and therefore cannot be treated in any other manner. I believe that the relation of the fuel to 1 cubic meter of kiln space is the most suitable, because it excludes the inequalities of the materials which are burnt in the kiln.

Of the 58 useful reports, the majority unfortunately belong to the continuous kilns; 20 use coal and 12 lignite; there are also 4 Cassel kilns, of which 2 use coal and 2 lignite, 12 down-draft kilns, 9 using coal and 3 lignite, and 7 old German kilns. There are about enough continuous kilns upon which to form an estimate of the conditions prevailing, but with the other kilns, the number does not suffice; the conditions are so different that one can deduce no average results from them. I will explain this further by the following example:

In the partially continuous kilns using coal, the consumption of fuel was found to be 140 kg. per cubic meter kiln space, then 122 and 207 kg. of lignite. In the Cassel kiln, there were used 243 kg. of coal, 86 kg. coal, and 180 of lignite. In the down-draft kilns we find similar values: for coal, we have 134, 148, 104, 106, 108, 108, 86, 75.5, 60.6; for lignite, 411, 285, 255. From this it will be seen that the number of results is too limited to give a fair average. In the continuous kilns, conditions are better, where we have 20 and 12 results. There the coal consumption averages 56.5 kg. with a minimum of 39 kg. and a maximum of 75 kg. With lignites, the minimum amounts to 53 kg., the maximum to about 142. I believe it would be the best plan to send out the circular once more, perhaps to a restricted circle, and to ask especially those manufacturers who have other than continuous kilns to make their returns. We have enough results for the continuous kilns, but we lack them for all other kiln systems.

There were many circulars returned in which we find marked "old brick kiln," "down-draft kiln" and finally, all the results are given for the continuous kiln and not for the old kilns. Those who build kilns and who generally have assistants around them who could supervise the correct filling-out of the circular, could render us a real service in the support of this circular. Mr. Dannenberg has thus filled out for us twenty-seven circulars in the most praiseworthy manner, and we owe it to him that we have obtained some material, for from the few circulars which were sent in direct, we obtained no results at all. So far, no results can be derived for the continuous kilns nor for the down-draft kilns for which we obtain 105 kg. coal as average fuel consumption. Still this compilation will lay claim to a certain value for the comparison of similar data, and we can at least compare conditions in brickyards which work under similar conditions. The task remaining is that we must strive to extend our tables, so that we may be in position to draw averages from a large number of separate observations.

No.	Name of the brick factory.	Character of the clay.	Analysis of the clay.	Color of the clay after burning.	The kiln system.	Capacity of the kiln. Cubic meters.
1	J. H. Hagenoh, Stade, Barnkrug.	Fat and silty marsh-clay.	Coarse sand... 2.9 Fine sand..... 19.7 Dust sand..... 25.3 Clay substance 52.1	Dirty red.	Two Hoffmann continuous kilns, one down-draft.	54.55 × 16 25.04 × 16 51.25
2	W. Schultz, Elbing, Gr. Steinort.	Fat, blue loam, with lime-pebbles and streaks of silt.	——	Light red to dark brown.	Continuous kiln.	49 × 16
3	Ascher, Storkow Stuttgarten.	Silty.	——	Red, white to green.	Continuous kiln.	52.70 × 12
4	Philip Holzmann, Frankfort-on-Main, Hainstadt.	Fat and lean lignite clays.	——	Yellowish gray to leather-brown. Light to dark red.	2 continuous kilns.	27 × 16
5	Evebeck, Brake.	1. Shaly clay. 2. White, sandy potter's clay. 3. Weathered, yellow clay, with flint.	——	Yellow-red, white, when hard burnt, yellow to brick-red.	3 Cassel kilns.	41.37
6	Stettin Portland Cement Company.	Septaria clay.	——	Light red.	Continuous kiln.	13.21 per chamber.
7	Preibisch, Reichenau, near Zittau.	Lignite clay.	SiO_2 .... 50.46 Al_2O_3 .... 33.93 Fe_2O_3 .... 3.44 CaO .... 0.24 MgO .... 0.38 K_2O .... 1.02 H_2O 11.50	Light to dark yellow.	Continuous kiln.	33.42 per chamber.
8	Pommeranian Industrial-Union, Berndshof.	Fat and lean diluvial clay.	SiO_2 .... 53.25 Al_2O_3 .... 11.55 Fe_2O_3 .... 6.68 CaO .... 10.85 CO_2 .... 8.76 MgO .... 1.92 SO_3 .... 0.32 H_2O 5.86	Red to yellowish.	Bührer and Hamel.	41.34 per chamber.

No.	Size of the furnaces.	Kind of fuel.	Weight of the fuel. Kilograms.	Cost per hektoliter. Marks.	Labor on the kilns.	Use of the waste heat.	Weight of the bricks. Kilograms.	Cost of burning per 1000 pieces. Marks.
1	Fuel scattered and burnt without grates.	Bituminous coal. Bituminous coal.	75 87.5–90	0.90–0.95	2 men, 9 hours.	For preheating kilns.	2.25 2.25	1.25–1.35
2	"	Nut coal. Bituminous coal.	79	1.10	2 men.	None.	3.50	3.50
3	"	93 hektoliters lignite and 7 hektoliters peat.	——	——	2 men.	None.	2.80	1.33
4	"	Bituminous coal.	80	4.00	2 men.	None.	3.75	4.00
5	1.25 × 3	"	——	1.20	——	For drying.	4.00	11.76–19.33
6	Fuel scattered and burnt without grates, using air conduits below.	"	82	1.10	2 men. 4.50	None.	3.08	1.88
7	Fuel scattered and burnt without grates.	"	85	——	2 men. 4.30	For drying.	4.00	5.00
8	" 12 holes.	"	79	80	2 men.	"	3.00	2.00

No.	Cost of burning per 1000 kilograms of ware. Marks.	Coal per cubic meter of kiln space. Kilograms.	Coal per 1000 pieces of ware. Kilograms.	Remarks.	Price per 1000 pieces. Marks.
1	0.56–0.60 ——	—— 119 Bituminous coal.	106 ——	Only bricks in the Hamburg size. In the old kiln, only roofing tiles.	13–16
2	1.00	71.5 Bituminous coal.	243.75	Brick of standard size. Roofing tile, ridge tile. Drain tile by way of exception.	Brick............ 27.00 Roof tile 42.00
3	0.475	10.5 Lignite. 2.3 peat.	358.66	Building brick.	22.00
4	1.07	48 Bituminous coal.	160	Standard size, one-quarter, one-half, three-quarter, and profile bricks.	15.00
5	2.94–4.83	184–302 Bituminous coal. 243 on the average.	613–999	Brick, sidewalk bricks. Floor tiles, border tiles.	300–900 (?)
6	0.61	40 Bituminous coal.	149.22	Brick and roofing tile.	Building brick .... 21.00 Roofing tile 34.00
7	1.25	69 Bituminous coal.	230	Building brick.	6.00
8	0.66	59 Bituminous coal.	197	Building brick, pressed brick, roofing tile, Holland pavers, ornamental building material.	20.00

No.	Name of the brick factory.	Character of the clay	Analysis of the clay.	Color of the clay after burning.	The kiln system.	Capacity of the kiln. Cubic meters.
9	Ernst March Sons, Charlottenburg.	Lignite clay, porcelain clay, ferruginous brick-clay, various clays from the Lausitz.	——	Lignite clays, yellow, the ferruginous clays, red.	Two-story down-draft kiln.	1st story......47.80 2nd story .....36.40 1st story......35.31 2nd story .....22.30 1st story......22.00 2nd story 17.37
10	Ludwig Kohrmann, Muskau.	Lignite clay.	——	Pale yellow to dark green.	Down-draft.	41.95
11	Rössler, Wächtersburg Whiteware factory.	Kaolin, lignite clays, quartz feldspar.	——	White.	Down-draft.	100 cubic meters for biscuit kiln; 78 cubic meters for the glost.
12	Ed. Peters, Vorsfelde.	Fat and lean ferruginous clay.	——	Light red to dark red.	Cassel kiln, old German kiln.	107.5 61.74
13	Seiffert, Liegnitz.	Ferruginous clay.	Coarse sand...... 7.1 Fine sand........16.5 Silt..............18.7 Clay substance ...57.7	Light red to dark blue.	Hoffmann continuous kiln.	About 20 cubic meters.
14	Hecht, Neuhof.	Calcareous clay.	SiO_2 ....53.55 Al_2O_3...........12.14 Fe_2O_3........... 4.50 CaO ....11.13 MgO .... 2.75 CO_2 .... 8.60 H_2O............ 3.00	Yellow to green.	Hoffmann continuous kiln.	31 × 12
15	Spater, Bretsch.	Silty loam, containing lime.	——	Cherry red to brown.	Semi-continuous kiln.	156.33
16	Ed. Lorenz, Plauen.	——	——	——	Old German kiln.	106.5
17	Daries, Plaue, Mecklenburg.	Part fat, part lean.	——	Light red to dark red.	Hoffmann continuous kiln.	19.20 × 14

o.	Size of the furnaces.	Kind of fuel.	Weight of fuel used. Kilograms.	Cost of the fuel used per hektoliter. Marks.	Labor on the kilns.	Use of the waste heat.	Weight of the bricks. Kilograms.	Cost of burning per 1000 pieces. Marks.
9	0.220 × 8 0.220 × 6 0.217 × 6	Bituminous coal.	75	1.60	Yellow wares, 2 men for 8 shifts. Red wares, 2 men for 6 shifts.	—	4.00	One story. Yellow ·15.00 Red .... 9.50 Yellow ·11.10 Red .... 6.90 Yellow ·14.44 Red .... 8.84 Two story. 8.50 6.80 8.06
10	0.42 × 3	Bituminous coal.	—	0.89	2 men.	For drying.	—	Chemical wares.
11	0.21 × 12 0.28 × 12	Best quality of bituminous coal from the Ruhr.	81.5	2.00	—	None.	30 % ware, 70 % material used in setting the ware.	White ware.
12	1.275 × 3	Wood and bituminous coal.	75	Wood 5.2 per square meter. Coal 0.75.	1–2 men.	—	3.60–3.75	5.00
13	Fuel scattered and burnt without grates.	Bituminous coal.	80	—	—	—	3.75–4.00	1.50
14	Fuel scattered and burnt without grates.	English bituminous coal.	65–70	—	2 men 4.5–5.0.	—	3.50	2.20
15	Grates 0.96 sq. meter and fuel scattered and burnt without grates.	Bohemian lignite.	62.5	0.50–0.60	1–2 men.	—	3.50	4–5.00
16	Simple grates.	Bituminous coal.	100	1.30	1–2 men.	None.	4.25	7.00
17	Fuel scattered and burnt without grates.	Peat and bituminous coal.	—	Peat, 1000 pieces .. 2.20 Coal ...... 1.50 Wood 4.50	2 men.	For kiln-drying the peat.	3.75	Peat alone ·2.93 Coal alone ·3.75 Peat and coal .....5.60 Wood alone 4.50

Number.	Cost of burning, per 1000 kilograms. Marks.	Coal per cubic meter of kiln space. Kilograms.	Coal per 1000 pieces of ware. Kilograms.	Remarks.	Price per 1000 pieces. Marks.
9	One story. Yellow ....3.75 Red ....2.38 Yellow ....2.28 Red ....1.72 Yellow ....3.60 Red ....2.21 Two stories. Yellow and red..2.12 Yellow and red..1.70 Yellow and red..2.02	Yellow ....134 (both stories) Red ....148 (one story) Yellow ....104 (both stories) Red ....106 (one story) Yellow ....108 (both stories) Red ....108 (one story) Bituminous coal.		Face-brick and terra cotta.	Not given.
10	—	86	—	Receptacles for chemical purposes, coils, pots, etc.	Not given.
11	—	Biscuit burn..75.5 Glost burn...60.6	—	White ware.	Not given.
12	1.36	0.08 cubic meter of wood. 89 of coal.	0.266 cubic meter of wood. 296.6 of coal.	Bricks, hollow bricks, roofing tile, floor tiles, drains and molded brick.	Brick ....27.00 Porous brick...33.00 Roofing tile...48–120 Floor tiles..80 to 200 Drains .....17 to 150
13	0.39	Not given.	—	Brick.	700 per 1000 kilograms.
14	0.65	49	151	Bricks, hollow bricks, drain-pipes, roofing tiles, floor tiles and terra cotta.	20.00
15	1.27	122	406	Brick.	10.00 per 1000 kilograms.
16	1.65	150 bituminous coal.	500	Brick.	7.00 per 1000 kilograms.
17	0.78 1.00 0.96 1.20	Peat ....93.7 Coal...........54.7 Wood (0.31 cubic meter).......1.00	312 peat. 182 coal. 1.00 wood.	Brick, face-brick, paving bricks, flat roofing tiles, etc.	Common bricks..28–30 Face-brick.......45–50 Roofing tile......32–35

Number.	Name af the brick factory.	Character of the clay.	Analysis of the clay.	Color of clay after burning.	The kiln system.	Capacity of the kiln. Cubic meters.
18	Daries, Plaue.	Silty clay, with marl concretions.	——	Yellow to green.	Hoffmann continuous kiln.	12.41×10
19	Jul. Matern, Rothenstein, near Koenigsberg.	A lean, stony, marl. It is washed.	——	Pale red.	2 Hoffmann continuous kilns.	28.04×24 28.04×16
20	C. Schmidt (Elbing), Alban Lentzen.	Coarse sand.....22.10 Fine sand.......11.60 Dust sand.......11.70 Silt............. 8.60 Clay substance ..46.00	SiO_2 ....56.56 Al_2O_3 ....13.72 Fe_2O_3 .... 4.70 CaO .... 9.43 MgO .... 1.78 K_2O .... 3.23 CO_2 .... 7.33 H_2O 3.35	Brown to red.	Bührer and Hamel.	26.3×18
21	Dr. Cohn, Splau Clay Works.	Fat and lean lignite clays.	——	Yellowish white to brownish yellow.	Semi-continuous.	109.28 cm.
22	Meisel, Muldenstein.	Lignite clays with very fine sand; kaolin clays.	Kaolin: Silica (comb) ...22.32 Silica (free).....42.32 Alumina ....23.99 MgO .... 0.48 CaO .... 0.33 Fe_2O_3 .... 0.87 K_2O .... 0.62 Loss on ignition. 8.48	Yellow to leather-brown; kaolin white to ashy gray.	Old German kilns.	2 kilns @ 122.89 1 kiln @ 111.60 1 kiln @ 182.00 1 kiln @ 97.20 1 kiln @ 289.18
					Cassel flame kilns.	4 kilns @ 97.96 2 kilns @ 108.34 1 kiln @ 150.16
23	Frederick Gebhardt, Sperenberg, Luckenwalde.	Upper clay, fat ferruginous loam without lime. Lower, calcareous loam.	——	Upper, light red to dark brown. Lower, brownish, flashing to red.	Dannenberg's continuous kiln.	16.28×12
24	Adolph Löwe, Neustadt-Magdeburg.	Ferruginous clay from the Elbe.	——	Pale red to brown.	Hoffmann-Dannenberg continuous kiln.	30×16

Number.	Area of the grates.	Kind of fuel.	Weight of the fuel. Kilograms.	Cost per hektoliter. Marks.	Labor on the kiln.	Use of the waste heat.	Weight of the bricks. Kilograms.	Cost of the burning per 1000 pieces. Marks.
18	Fuel scattered and burnt without grates.	Peat and bituminous coal.	Peat per 1000 pieces, 225. Coal, 70.	Peat per 1000 pieces, 2.00. Coal, 1.42.	2 men.	For drying out the peat.	3.50	Peat alone . 2.75 Coal .... 4.25 Peat and coal 3.60
19	"	Bituminous coal.	65	0.38–0.45	2 men.	For drying.	4.00	1–150
20	"	"	75	——	2 men.	——	4.00	2.04
21	Grates 0.90×3. Fuel also scattered and burned without grates.	Lignite coal.	63	0.50–0.60	1 or 2 men.	For drying.	4.00	10.00
22	Grates 0.90 m.	Earthy lignite, bituminous coal, and briquettes.	70–80	0.20	1 or 2 men.	——	4.00	6–10
	Porous bricks.	——	70–80	0.20	1 or 2 men.	For the heating-up of the kilns.	2–2.50	0.5–1.0
23	Fuel scattered and burned without grates.	Bohemian lignites.	1.25	——	——	For the heating-up of the kilns.	3.60	——
24	" 12 fireholes.	"	63	0.80	——	——	3.38	1.24

No.	Cost of burning per 1000 kilograms. Marks.	Coal per cubic meter of kiln space. Kilograms.	Coal per 1000 pieces of ware. Kilograms.	Remarks.	Price per 1000 pieces. Marks.
18	0.81 1.22 1.03	Peat......99.7 Coal......67.7	Peat .....332 Coal 228	Tile, face-brick and drain pipe.	Building-brick.. 28–30
19	0.25–0.29	35–43 bituminous coal, 39 on the average.	130	Brick.	26–28
20	0.51	59 bituminous coal.	196.6	Brick.	——
21	2.50	184–230 lignite, 207 average.	690	Only $^1/_4$, $^1/_2$, or $^3/_4$ brick; hollow brick and ornamental building material.	30.00 per 1000 kg.
22	1.50–2.50	Up to 380 of earthy lignite.	Up to 1266	Solid and hollow bricks .... Paving-bricks..... .... Solid face-brick and simple façade brick .... Fire-brick .... Refractory materials .... Floor tiles	22–27 26–70 50–70 65–80 3–10 per 100 kg. 65–120
	0.25–0.44	Up to 65 of earthy lignite.	Up to 217	Only porous wares obtained by mixture of lignite into clay body.	——
23	——	53 Bohemian lignite.	189	Building brick and roofing tile.	Building brick .....21.00 Roofing tile........30.00
24	0.37	54 lignite.	180	Building brick and roofing tile.	Building brick .....27.00 Roofing tile.......100.00

Number.	Name of the brick factory.	Character of the clay.	Analysis of the clay.	Color of the clay after burning.	The kiln system.	Capacity of the kiln. Cubic meters.
25	C. Gottschalk, Obendorf, near Amendorf.	Somewhat refractory, lignite clay.	——	Flesh-red to light yellow.	Four Cassel kilns.	About 90
26	Brelochowsky, Oels, Leuthen.	Medium fat loam, marly in lower portion.	——	Light red to dark red and brown.	Dannenberg continuous kiln.	About 19.6×14
27	Moritz Lobien, Wallessdorf, near Prieburg.	Bowlder loam with basaltic detritus.	——	Light red to dark red and brown.	Dannenberg continuous kiln.	41×12
28	Bachem Steam Brick Works, Stift Fischbeck.	River loam, pure and fat.	——	Light red, dark red to brown.	Hoffmann-Dannenberg continuous kiln.	37×18
29	A. Liffer and Son, Poln. Peterwitz.	Fat deposits, in great part strongly ferruginous.	——	Light red to dark red.	Dannenberg continuous kiln.	21×14
30	Carl Lobin, Zug, near Brand, Saxony.	Bowlder loam, fat, containing stone detritus.	——	Light red, dark red to brown.	Two old German kilns.	90
31	Harmening, Breslau Alt Scheitnitz.	Fat, river loam, fine, silty, and strong.	——	Light red to brown.	Dannenberg continuous kiln.	24×16
32	Heised Steam Brick Works, W. Liecke.	Red, river loam and calcareous marls.	——	Light red to brown; and flashing red.	Hoffmann continuous kiln.	33×16
33	Vockrodt, Mühlhausen, in Thuringia.	Marly bowlder loam, calcareous and ferruginous clay.	——	Light red to brown; pale red to brown.	Rühne-Dannenberg continuous kiln.	23×14
	"	——	——	——	Semi-continuous kiln.	28
34	Th. Griesenau Steam Brick Works, near Rothensee.	River loam, partly fat and partly lean.	——	Light red to dark red.	Hoffmann-Dannenberg continuous kiln.	17.5×14

Number.	Area of the grates.	Kind of fuel.	Weight of the fuel. Kilograms.	Cost per hektoliter. Marks.	Labor on the kiln.	Use of the waste heat.	Weight of the bricks. Kilograms.	Cost of the burning per 1000 pieces. Marks.
25	Flat grates.	Earthy lignite.	75	0.25	——	——	3.50	1.75
26	Fuel scattered and burnt without grates.	Upper Silesian bituminous coal.	92	——	0.75 per M.	Preheating.	3.50	2.10
27	"	Bohemian lignite.	90	0.50	0.80 per M.	"	3.42	3.00
28	" 15 holes.	Westphalian bituminous coal.	——	——	0.50 per M.	"	3.38	——
29	" 9 holes.	Upper Silesian "slack" coal.	90	1.04	0.60 per M.	"	3.75	1.90
30	Narrow grates.	Bituminous coal.	80	0.99	0.60 per M.	——	3.58	6.00
31	Fuel scattered and burnt without grates. 9 holes.	"	——	0.52 per cwt.	0.50 per M.	Preheating.	3.67	1.50–2.00
32	" 16 holes.	Westphalian bituminous coal.	——	——	——	Water-smoking.	3.00	2.00
33	"	"	——	0.80 per cwt.	1.25 per M.	"	3.25–4.00	4.00
	——	——	——	——	——	——	——	7.50
34	" 9 holes.	Bohemian lignite.	75	0.45–0.70	0.50–0.60 per M.	Water-smoking.	3.47	2.50–3.00

Number.	Cost of burning per 1000 kilograms. Marks.	Coal per cubic meter of kiln space. Kilograms.	Coal per 1000 pieces of ware. Kilograms.	Remarks.	Price per 1000 pieces. Marks.
25	0.50	165–195 Earthy lignite. 180 average.	527	Building brick and porous brick.	——
26	0.60	62 Silesian bituminous coal.	200	40 per cent shingle tile and drain pipes. 10 per cent better grade building brick. 50 per cent backing-up brick.	Backing-up brick, 24–25. Roofing tile and drain pipes, 30.
27	0.88	104 Lignite.	292	Building brick and roofing tile.	Building brick, 16–22. Roofing tile, 27.00.
28	———	52 Westphalian bituminous coal-dust.	173	Face-brick, building brick, pan tiles, and drain pipes.	Face-brick, 36–40. Building brick, 22.50. Ridge tiles, 45–48.
29	0.51	51 Upper Silesian coal.	165	Building brick, roofing tile, and drain pipes.	19–21
30	1.67	144 Bituminous coal.	482	Building brick.	24
31	0.41–0.54	52–60 Bituminous coal. 56 in average.	186	Face-brick, paving brick, hard-burnt brick.	Face- and paving brick, 27.00. Hard brick, 24.00.
32	0.66	60	200	60 per cent face-brick. 30 per cent drain pipes. 10 per cent building brick.	——
33	1.00–1.23	75 Bituminous coal.	250	Brick and roofing tile. (Lime and gypsum.)	——
	1.88–2.31	140 Bituminous coal.	466	"	——
34	0.75–0.87	77 Bohemian lignite.	250	Face-brick and roofing tile, etc.	24 to 40

Number.	Name of the brick factory.	Character of the clay.	Analysis of the clay.	Color of the clay after burning.	The kiln system.	Capacity of the kiln. Cubic meters.
35	F. Möbius, Elbing, Succase.	Pure glacial clay.	———	Pale red to dark red.	Dannenberg continuous kiln.	43×16
36	Throtha-Sennewitz Brick Works, (Mangold).	Saggar clay, some calcium sulphate, 10-15 per cent alum.	———	Flesh-red, white or yellow.	Hoffmann and Dannenberg continuous kilns.	33×18 27×16
37	Max Füllner, Poppeln, near Havelberg.	1—River loam from the Elbe. 2—Impure calcareous clay.	———	1—Light red to brown. 2—White to yellow, flashing red.	2 arched kilns with chimneys.	About 100 and 120.
38	H. Packe, Neustadt, Upper Silesia.	Mellow, silty, ferruginous, glacial clay.	———	Light red to dark red.	Dannenberg continuous kiln. 2 old German kilns.	33×14 About 166.
39	Jasper Möller, Elmshorn.	1—River clay from the Elbe. 2—Lean, glacial clay.	No. 2. Effervesces a little with acid.	Light red to dark red. Dark red to blackish.	1 Dannenberg continuous kiln. 1 Hoffmann continuous kiln. 2 down-draft kilns.	15×16 18.9×16 Holding 75 M. Hamburg size brick.
40	Franz Leisebein, Gundorf, near Leipzig.	River clay, fat and lean, silty.	———	Pale, light and dark red.	1 Hoffmann continuous kiln. 1 Dannenberg continuous kiln.	55.5×14 46.8×16
41	Kieszler, Grünberg, Heinersdorf.	Fat, glacial clay, marly in upper parts.	———	Light red to dark red and black.	2 down-draft kilns.	67

Number.	Area of the grates.	Kind of fuel.	Weight of the fuel. Kilograms.	Cost per hektoliter. Marks.	Labor on the kiln.	Use of the waste heat.	Weight of the bricks. Kilograms.	Cost of the burning per 1000 pieces. Marks.
35	Fuel scattered and burnt without grates. 16 holes.	English bituminous coal.	74	0.45–0.80	4.20 per M.	For water-smoking.	4.02	2.50
36	" 16 and 9 holes, respectively.	Earthy lignite.	70	0.39	0.40 per M.	"	3.88	1.50
37	——	Bohemian lignite and wood.	63	0.68	2.00 per M.	——	1—3.48 2—3.52	7.00
38	" 12 holes. Each has 8 flat grates, 0.66 sq. meter.	Upper Silesian bituminous coal.	——	0.35 per cwt.	0.30–0.40 per M.	For water-smoking.	3.50	1.26
							3.50	3.06
39	Fuel scattered and burnt without grates. Ditto, fuel burnt by experimental method.	Mine-run coal.	——	2.75 per cwt.	2 men at 1.00 per M.	Preheating.	1—2.22 2—2.42 Hamburg size.	1.95
						Not used.		2.85
40	Fuel scattered and burnt without grates.	Earthy lignite and bituminous coal.	——	0.34 per cwt. for earthy lignite. (Meuselwitz)	0.36	Not used.	3.50	2.18
				0.82 for bituminous coal.	0.36	For preheating.	——	2.93
41	5 grate fireplaces, one-sided, 0.47×1.77	Earthy lignite and bituminous coal.	70	0.50 1.00 per cwt.	— —	Carried over from one kiln to another.	3.90	9.00

Number.	Cost of burning per 1000 kilograms. Marks.	Coal per cubic meter of kiln space. Kilograms.	Coal per 1000 pieces of ware. Kilograms.	Remarks.	Price per 1000 pieces. Marks.
35	0.59	65 bituminous coal.	225	Face-brick, solid and hollow brick, shingle tiles and building brick.	——
36	0.38	137–148 earthy lignite. Average, 142.	473	Face-brick, roofing tile, pipes, 60–70 per cent. Backing-up material (common brick).	27.00 on the average. (22–60)
37	1.99–2.01	208–214 Bohemian lignite and 0.04 wood. 211 in average.	638	Building brick and roofing tile.	27–30
38	0.36	54	180	Pipes and roofing tile.	——
	0.87	90	300	"	——
39	0.88 1.18	—— ——	—— ——	——	——
40	0.62	54 lignite. 148 bituminous.	80 47	Only building brick.	28.00
	0.84	66 lignite. 20 bituminous.	220 66	——	——
41	2.31	355 earthy lignite. 28 bituminous.	1183 93	Building brick, pipes, roofing tile.	——

Number.	Name of the brick factory.	Character of the clay.	Analysis of the clay.	Color of the clay after burning.	The kiln system.	Capacity of the kiln. Cubic meters.
42	J. G. Semmel, Aga, near Gera.	Lignite clays, kaolin; strong, very fat, hard clay.	Free from lime.	Rose, whitish yellow, white, light red, to brown.	Dannenberg's continuous kiln.	25 × 16
43	J. G. Köhler, Aalsgard, Teglwerk in Sellebeck.	Fat bowlder clay.	——	Light to dark red.	"	25 × 14
44	Fredricksholm, Aktien Gesellschaft, Copenhagen, Denmark.	Calcareous clay.	——	White to yellow and gray. Flashes red.	1 Dannenberg, 1 Hoffmann and 1 Mendheim kiln, all continuous.	53 × 15 27 × 24 24 × 16
45	Hüpeden, Mengelsdorf.	Bowlder clay, lean and strong.	——	Light, dark red and brown.	1 Wojaczek continuous kiln, modeled after Dannenberg's.	25 × 15
46	W. Göttschke, Zerbst.	Lean, hard clay, fat, common clay.	Calcareous.	Light to dark red, with white spots.	1 Dannenberg continuous kiln.	15 × 14
47	Scholtz, Durgoy.	Lean, bowlder clay.	——	Light to dark red.	1 old German kiln, 1 Dannenberg continuous kiln.	166 24 × 14
48	Fr. Schlobach, Böhlitz, near Ebsenburg.	Silty, river clay, fluctuating from fat to lean.	——	Pale, light, to dark red.	1 Dannenberg continuous kiln.	26 × 14
49	V. von Gröling and Lubowsky, Schalscha, near Gleiwitz.	Fat clay preponderates; finely silty with large stones and nearly concretions.	——	Pale, grayish red, light red to dark red.	1 Hoffmann continuous kiln.	20.7 × 14
50	B. Wustemann, Welkau.	——	——	——	Down-draft kiln.	——
51	Nikolai, Friedberg, Saxony.	——	——	——	Down-draft kiln.	——

Number.	Area of the grates.	Kind of fuel.	Weight of the fuel. Kilograms.	Cost per hektoliter. Marks.	Labor on the kiln.	Use of the waste heat.	Weight of the bricks. Kilograms.	Cost of the burning per 1000 pieces. Marks.
42	12 firing-holes.	Bohemian bone-coal. Meuselwitz coal.	63 70	—	0.90	— —	4.38 4.49	—
43	8 firing-holes.	English bituminous coal.	—	1.13	2 men at 0.90.	For water-smoking.	2.50	2.90 for the Hamburg size.
44	20 holes. 16 holes. 12 holes.	"	—	1.10 per cwt.	2 men at 0.40 per M.	"	2.35	3.80 for the Hamburg size.
45	9 holes; permanent heat shaft.	Bohemian lignite.	63	0.61	2 men at 0.50 per M.	"	3.76	1.95
46	6 holes.	"	63	0.69	"	"	3.75	3.27
47	6×0.40 9 holes.	Upper Silesian bituminous coal. Slack.	— —	— 0.50 per cwt.	0.60 per M.	"	3.64 3.64	— 1.75
48	9 holes.	Bohemian lignite.	—	0.06 per cwt.	2 men at 0.50 per M.	"	3.46	2.40
49	9 holes. —	Upper Silesian nut coal, good quality.	—	0.30–0.37 per cwt.	"	Not used.	3.60	0.90 to 1.22
50	—	Bohemian nut coal.	—	0.55 per cwt.	—	—	—	10
51	—	"	—	0.51 per cwt.	—	—	—	7.65

Number.	Cost per 1000 kilograms. Marks.	Coal per cubic meter of kiln space. Kilograms.	Coal per 1000 pieces of ware. Kilograms.	Remarks.	Price per 1000 pieces of ware. Marks.
42	——	100–125 lignite, 112.5 on average.	326–420	Face-brick, solid and hollow brick, roofing tile, encaustic tile, pipes.	——
43	1.16	——	128	Building brick.	23 kr. per M.
44	1.61	——	140	Building brick.	20.00
45	0.52	75 Bohemian lignite.	250	Building brick, face-brick and shingle tile.	——
46	0.87	90 lignite.	300	Building brick, shingle tiles and pipes.	Building brick 24.00
47	0.43	120 lump coal, 51 slack coal.	400 175	Only common brick.	Roofing-tile 27–30
48	0.69	58 lignite.	200	Building brick.	28–30
49	0.25–0.34	45–53 bituminous coal of good quality, 49 in the average.	150–175	Building brick, ridge tile.	——
50	——	270–300 Bohemian nut coal.	950	Building brick.	——
51	——	225 Bohemian nut coal.	750	Building brick.	——

CONTINUOUS KILNS

A. KILNS FOR THE LIGNITE CLAYS

(*a*) For Bituminous Coal Firing

Series number.	Name of the brick works.	Color of the burnt clay.	Size of the kiln chamber. Cubic meters.	Firing-holes per chamber.	Number of brick per cubic meter of kiln capacity.	Weight of one brick. Kilograms.	Weight of a cubic meter of kiln space. Kilograms.
1	Kunitzen, Weiche.	Yellow-red to brown.	70	30	300	3.8	1140
2	Seyffert, Liegnitz.	Yellow-red to dark brown.	23	9	293	3.75	1100
3	Preibisch, Zittau.	Light to dark yellow.	32	9	350	4.00	1400
4	Holzmann, Frankfurt-on-Main.	Yellow to leather-brown, light to dark red.	27	—	300?	4.00	1200?
5	Delbrück, Stettin.	Light red to dark red.	13	6	255	3.08	886
	(*b*) For (Bohemian) Lignite						
1	Semmel, Gera.	Rose, white, light red, brown.	25	12	300?	4.44	1314
	MENDHEIM GAS KILN FOR LIGNITE CLAYS WITH (BOHEMIAN) LIGNITE						
1	Splau, Domitsch, A. G.	Yellow to leather-brown.	35	—	240	4.25	1020
	(*c*) For Earthy Lignite						
1	Kuhnt, Halle, A. S.	Flesh-colored to yellowish white.	15	5	300?	3.50	1050
2	Trotha, Sennewitz, A. G.	Flesh-red, white, yellow.	33	16	300?	3.88	1164

CONTINUOUS KILNS

A. Kilns for Lignite Clays

(*a*) For Bituminous Coal Firing

Series number.	Weight per hektoliter of coal. Kilograms.	Cost per hektoliter of coal. Pfennigs.	Weight of coal.		Cost of coal.		Hand or machine. Soft or stiff mud.	Setting dry or damp.	Building brick, paving brick, or face-brick.
			Per cubic meter of kiln space. Kilograms.	Per 100 kilos of clayware. Kilograms.	Per cubic meter of kiln space. Pfennigs.	Per 1000 bricks. Pfennigs.			
1	65	52	55	4.8	44	147	Machine. Stiff.	Damp.	Building brick and pavers 6 : 1.
2	80	67	51	4.7	43	147	"	"	Building brick.
3	85	141	66	4.7	109	311	"	Dry.	Hard burnt.
4	80	400 ?	48	4.0	240	800	—	—	Face-brick.
5	80	125	46	5.2	72	282	Machine. Soft.	Dry.	Building brick.
			Average 53						
(*b*) For (Bohemian) Lignite									
1	67	—	112	8.5	—	—	—	—	Face-brick.
Mendheim Gas Kiln for Lignite Clays, with (Bohemian) Lignite									
1	65	65	223	22.0	223	903	Machine. Medium stiff.	Dry.	Pavers. Face-brick.
(*c*) For Earthy Lignite									
1	70 ?	32	168	16.0	77	250	Machine.	Damp.	Building brick.
2	70	39	142	12.2	79	263 ?	—	—	Face-brick.
			Average 155						

CONTINUOUS KILNS

A. Kilns for Lignite Clays

(*a*) For Bituminous Coal Firing

Series number.	Accessory charge.	Size of brick. Centimeters.	Per cent of rejected material.	Firing periods. Minutes.	Use of the waste heat.	Cycle of the kiln. Days.	Remarks.
1	Roofing tiles. Drain pipe. Face-brick.	Standard.	0.07	20 (10 and 10)	None.	24	Water-smoked through the doors
2	"	"	$^1/_2$–1	10	Water-smoking.	12–14	
3	Face and shape brick.	25 : 12 : 6.7 "	3	5	Drying.	14	
4	Shape brick.	Standard.	—	—	None.	—	
5	None.	Standard.	4–5	3	Drying.	$12^1/_2$	Septaria clay.
			(*b*) For (Bohemian) Lignite				
1	Roofing tile, sidewalk tiles, pipes.	1	—	—	—	—	Bohemian bone coal and Mäuselwitz coal.
			Mendheim Gas Kiln for Lignite Clays, with (Bohemian) Lignite				
1	Interlocking tile, glazed terra cotta.	Standard.	5	60 to 90	Drying.	32	
			(*c*) For Earthy Lignite				
1	None.	Standard.	5–25	30	None.	8	Rejected ware only when set wet. Clays from the "Bunt Sandstein" formation.
2	Roofing tile, pipes and 60–70 per cent (common brick).	Standard.	—	—	Water-smoking.	—	Lignite clay mixed with kaolin, gypsum and alum.

CONTINUOUS KILNS

B. KILNS FOR DRIFT CLAYS

(*a*) For Bituminous Coal Firing

Series number.	Name of brick works.	Color of the burnt clay.	Size of the kiln chamber. Cubic meters.	Firing-holes per chamber.	Number of bricks per cubic meter of kiln capacity.	Weight of one brick. Kilograms.	Weight of a cubic meter of kiln space. Kilograms.
1	Rasch, Oeynhausen.	Yellowish red to brown.	32	2–3	325	4.00	1300
2	Von Gröling and Lubowsky, Gleiwitz.	Gray-red, light red, dark red.	21	9	300 ?	3.60	1080
3	Daries, Plau in Mecklenburg.	Light red to dark red.	19	—	300 ?	3.75	1125
4	Brelowsky, Oels.	Light red to dark brown.	20	—	300 ?	3.50	1050
5	Lisser, Peterwitz.	Light red to dark red.	21	9	300 ?	3.75	1125
6	Link, Ueckermünde.	Light red, dark red, brownish.	52	20	271	3.50	950
	(*b*) For (Bohemian) Lignite						
1	Gebhardt, Sperenberg.	Light red to dark brown.	16	—	300 ?	3.60	1080
2	Labin, Prieberg.	Light red to dark brown.	14	—	300 ?	3.42	1026
3	Götschke, Zerbst.	Light red to dark red, white specks.	15	6	300 ?	3.72	1125
	(*c*) For Earthy Lignite						
–	—	—	—	—	—	—	—

CONTINUOUS KILNS

B. KILNS FOR DRIFT CLAYS

(*a*) For Bituminous Coal Firing

Series number.	Weight per hekto-liter of coal. Kilograms.	Price per hektoliter of coal. Pfennigs.	Weight of coal.		Cost of coal.		Hand or machine. Soft or stiff mud.	Setting. Dry or damp.	Building brick, paving brick or face-brick.
			Per cubic meter of kiln space. Kilograms.	Per 100 kilo-grams of clay-wares. Kilograms.	Per cubic meter of kiln space. Pfennigs.	Per 1000 bricks. Pfennigs.			
1	75	86	45	3.5	52	160	Machine. Medium soft.	Dry.	Face-brick. Hard burnt.
2	—	34 per cwt.	49	4.6	33	110	—	—	Building brick.
3	70	150	55	4.9	118	393 ?	—	—	Building brick. Face-brick. Paving brick.
4	92	310 ?	62	5.9	63	210	—	—	Building brick.
5	90	104	51	4.5	59	197	—	—	"
6	76	73	76	8.0	73	280	Both.	—	"
			Average 56						

(*b*) For (Bohemian) Lignite

1	63	—	53 ?	5.0	—	—	—	—	"
2	90 ?	50	104	10.1	58	193	—	—	"
3	63	69	90	8.0	99	330	—	—	"
			Average 97						

(*c*) For Earthy Lignite

–	—	—	—	—	—	—	—	—	

CONTINUOUS KILNS

B. KILNS FOR DRIFT CLAYS

(*a*) For Bituminous Coal Firing

Series number.	Accessory charge.	Size of brick.	Per cent of rejected material.	Firing periods. Minutes.	Use of the waste heat.	Cycle of the kiln. Days.	Remarks.
1	Terra cotta. Interlocking roofing tile.	Standard.	10	20	Only radiated heat for drying.	18	Ferruginous clay, fat, mixed with schistose rock.
2	Interlocking roofing tile.	"	—	—	None.	—	
3	Roofing tile.	"	—	—	For kiln-drying peat.	—	When peat is used, 94 kilograms per cubic meter, costing 293 pfennigs.
4	Pipes. Roofing tile.	"	—	—	Water-smoking.	—	Medium fat, *drift clay*.
5	Roofing tile. Pipes.	"	—	—	"	—	Fat, ferruginous *loam*.
6	Roofing tile. Pipes.	"	1–2	30	None.	16	
	(*b*) For (Bohemian) Lignite						
1	Roofing tile.	"	—	—	Water-smoking.	—	Upper layers, fat and ferruginous without lime. Lower calcareous.
2	"	"	—	—	"	—	
3	Roofing tile. Pipes.	"	—	—	"	—	Lean and fat, *drift* clay; somewhat calcareous.
	(*c*) For Earthy Lignite						
–	—	—	—	—	—	—	—

CONTINUOUS KILNS

C. Kilns for Alluvial Clays

(*a*) For Bituminous Coal Firing

Series number.	Name of the brick works.	Color of the burnt clay.	Size of the kiln chamber. Cubic meters.	Firing-holes per chamber.	Number of bricks per cubic meter of kiln capacity.	Weight of one brick. Kilograms.	Weight of a cubic meter of kiln space. Kilograms.
1	Schulz, Elbing.	Pale red to dark brown.	31	12	300?	3.50	1050
2	Schmidt, Elbing.	Red to brown.	26	9	385	4.00	1340
3	Möbus, Elbing.	Pale red to dark red.	43	16	300?	4.02	1206
4	Harmening, Breslau.	Light red to brown.	24	9	300?	3.67	1101
5	Bachem Brick Works.	Light to dark red, brown.	37	15	300?	3.38	1014
6	Leisebein, Leipzic. " "	Pale red to dark red.	56 47	— —	300? 300?	3.50 3.50	1050 1050
7	Möller, Elmshorn.	Light red to dark red.	15	—	300?	2.22	—
8	J. H. Hagenah, Stade.	Dirty red.	55	—	400–450	2.25	956
	(*b*) For (Bohemian) Lignite						
1	Matthes, Rathenow.	Light red to brown-red.	17?	11 and 12	300?	3.50	1050
2	Löwe, Neustadt-Magdeburg.	Pale red to brown.	30	12	300?	3.38	1014
3	Griesenau, Rothensee.	Light red to dark red.	18	9	300?	3.47	1041
4	Schlobach, Ebsenberg.	"	26	9	300?	3.46	1038
5	Altmann, Tippleskirchen.	Red to dark brown and black.	22	9	300?	3.35	1005
	(*c*) For Earthy Lignite						
1	Schaaf, Halle.	Red to greenish black.	45	12	360	3.50	1260

CONTINUOUS KILNS

C. Kilns for Alluvial Clays

(*a*) For Bituminous Coal Firing

Series number.	Weight per hekto-liter of coal. Kilograms.	Cost per hektoliter of coal. Pfennigs.	Weight of coal.		Cost of coal.		Hand or machine. Soft or stiff mud.	Setting dry or damp.	Building brick, paving brick, or face-brick.
			Per cubic meter of kiln space. Kilograms.	Per 100 kilos of clayware. Kilograms.	Per cubic meter of kiln space. Pfennigs.	Per 1000 bricks. Pfennigs.			
1	75	105	58	5.5	81	270	Hard. Soft mud.	Damp.	Building and paving brick.
2	75	105	59	4.9	81	210	—	—	Building brick.
3	74	63	65	5.4	55	183	—	—	Building and face-brick.
4	—	52 per cwt.	56	5.1	58	193	—	—	Building, face- and paving brick.
5	—	—	52	5.00	—	—	—	—	Building brick.
6	—	34 per cwt. lignite.	54 lignite. 48 bit. coal.	19.00	—	—	—	—	"
		0.82 per cwt. bit. coal.	66 lignite. 20 bit. coal.	8.2	—	—	—	—	"
7	—	275 per cwt.	—	—	—	—	—	—	"
8	100	64	—	—	51	120	—	—	"
			Average 58						

(*b*) For (Bohemian) Lignite

1	65	80	87	8.3	107	357	Both. Soft mud.	Damp.	Building and face-brick.
2	63	80	54	5.3	69	230	—	—	Building and face-brick.
3	75	58	77	7.4	59	197	—	—	Building and face-brick.
4	—	6 per cwt.	58	5.6	7?	23?	—	—	Building brick.
5	65	105	47?	4.7	76	253	Both.	Damp.	"
			Average 69						

(*c*) For Earthy Lignite

1	71	28	71	5.7	28	93	Both. Soft mud.	Damp.	Face-brick Building brick.

CONTINUOUS KILNS

C. Kilns for Alluvial Clays

(*a*) For Bituminous Coal Firing

Series number.	Accessory charge.	Size of brick.	Per cent of rejected material.	Firing periods. Minutes.	Uses of the waste heat.	Cycle of the kiln. Days.	Remarks.
1	Roofing tiles.	Standard.	1–2	15	Drying and water-smoking.	16-18	
2		"	—	—	—	—	
3	Hollow brick and roofing tile.	"	—	—	Water-smoking.	—	
4		"	—	—	"	—	
5	Roofing tile pipes.	"	—	—	"	—	
6		"	—	—	None	—	Hoffmann ring kiln } Mixture of bituminous coal and earthy lignite.
		"	—	—	Water-smoking.	—	Dannenberg ring kiln
7		Hamburg size 23x11x5.5.	—	—	"	—	
8		"	—	—	"	—	

(*b*) For (Bohemian) Lignite

Series number.	Accessory charge.	Size of brick.	Per cent of rejected material.	Firing periods. Minutes.	Uses of the waste heat.	Cycle of the kiln. Days.	Remarks.
1	Roofing tile.	Standard.	7	60	None.	16	Three chambers under fire.
2	Interlocking roof tiles.	"	—	—	—	—	
3	"	"	—	—	Water-smoking.	—	
4	———	"	—	—	"	—	Silty alluvial clay, moderately fat.
5	Flower pots.	"	2	5	None.	10	Unmixed clay.

(*c*) For Earthy Lignite Coal

Series number.	Accessory charge.	Size of brick.	Per cent of rejected material.	Firing periods. Minutes.	Uses of the waste heat.	Cycle of the kiln. Days.	Remarks.
1	Roofing tile.	"	0.6-0.7	12	Sometimes for drying.	10.12	Clay from the Saale, with some from the "burnt sand stein," formation and some lime.

CONTINUOUS KILNS

D. KILNS FOR MARL CLAYS

(*a*) For Bituminous Coal Firing

Series number.	Name of the brick works.	Color of the burnt clay.	Size of the kiln chamber. Cubic meters.	Number of firing holes per chamber.	Number of bricks per cubic meter of kiln capacity.	Weight of one brick. Kilograms.	Weight of a cubic meter of kiln space. Kilograms.
1	Link, Ueckermünde.	White to yellow.	58	20	300?	3.12	936
2	"Merkur," A. G.	"	80	15	300?	3.85	1155
3	Hecht, Neuhof.	Yellow to green.	31	—	300?	3.50	1050
4	Pommerscher Industrie-Verein, Bernshof.	Red to yellow.	41	12	300?	3.00	900
5	Daries, Plan, in Mecklenberg.	Yellow to green.	12	—	300?	3.50	1050
6	Lieck, Heisede.	Light red to white-red, flashed.	33	16	300?	3.00	900
7	Rasch, Oehnhausen.	Reddish to brownish green.	22	2–3	325	4.00	1300
8	Jordt, Flensburg.	Yellow to green.	66	15	300	3.25	975
9	Fredericksholm Actien-Gessellschaft.	White, yellow, gray.	53	20	—	2.35	—
	(*b*) For (Bohemian) Lignite						
–	——	——	—	—	—	—	—
	(*c*) For Earthy Lignite						
1	Ascher, Storkow.	Yellow to green.	48	12	300?	2.80	840
2	Meyer, Streganz.	White to yellow.	46	15	300?	3.25	975
3	Schulze, Zossen.	"	39	20	242	3.20	775

CONTINUOUS KILNS

D. Kilns for Marl Clays

Series number.	Weight per hektoliter of coal. Kilograms.	Cost per hektoliter of coal. Pfennigs.	Weight of coal.		Cost of coal.		Hand or machine. Soft or stiff mud.	Setting. Dry or damp.	Building brick, paving brick, or face-brick.
			Per cubic meter of kiln space. Kilograms.	Per 100 kilograms of clay-ware. Kilograms.	Per cubic meter of kiln space. Pfennigs.	Per 1000 bricks. Pfennigs.			
(a) For Bituminous Coal Firing									
1	76	73	69	7.4	66	220	Both.	—	Building brick.
2	78	80	61 ?	5.3	63	210	Both, stiff mud.	Dry.	Face-brick.
3	68	—	49	4.7	66	220	—	—	Building and face-brick.
4	79	80	59	6.6	60	200	—	—	"
5	70	142	68	6.5	138	460	—	—	"
6	—	—	60 ?	6.7	60	200	—	—	"
7	75	86	50	3.9	57	175	Machine. Medium soft.	Dry.	Face-brick and hard brick.
8	—	69 per cwt.	75	7.7	104	347	Machine. Stiff mud.	Damp.	Building brick.
9	—	110 per cwt.	—	—	—	380	—	—	"
			Average 62						
(b) For (Bohemian) Lignite									
—	—	—	—	—	—	—	—	—	—
(c) For Earthy Lignite									
1	62	20	120	14.3	39	130	Hand. Soft mud.	Damp.	Building and paving brick.
2	75	35	140	14.4	65	217	"	"	Building brick.
3	60	33	94	12.1	52	215	"	"	"
			Average 118						

CONTINUOUS KILNS

D. KILNS FOR MARL CLAYS

(*a*) For Bituminous Coal Firing

Series number.	Accessory charge.	Size of brick.	Per cent of rejected material-	Firing periods. Minutes.	Use of the waste heat.	Cycle of the kiln. Days.	Remarks.
1	Hollow brick drain tile.	Standard.	1–2	30	None.	16	
2	———	"	5	60	Drying.	14	
3	Drain tile. Roofing tile.	"	—	—	———	—	
4	Roofing tile and build'g ornaments.	"	—	—	Drying.	—	
5	Drain tile.	"	—	—	For kiln-drying peat.	—	
6	"	"	—	—	Water-smoking.	—	Mixture of red alluvial clay and calcareous marl.
7	Interlocking roofing tile.	"	10	20	Drying, using only radiated heat.	16	Silty, calcareous, ferruginous marl.
8	None.	"	2	30	None.	18–20	Generally use the Hamburg size.
9	———	Hamburg size.	—	—	Water-smoking.	—	

(*b*) For Bohemian Lignite

(*c*) For Earthy Lignite

1	None.	Standard.	1	15	None.	14	
2	"	"	11	—	"	14	
3	"	"	1	10–15	"	10–11	

CONTINUOUS KILNS

E. Kilns for Loams

(*a*) For Bituminous Coal Firing

Series number.	Name of the brick works.	Color of the burnt clay.	Size of the kiln chamber. Cubic meters.	Number of firing-holes per chamber.	Number of bricks per cubic meter of kiln capacity.	Weight of one brick. Kilograms.	Weight of a cubic meter of kiln space. Kilograms.
1	Matern, Königsberg.	Red to brownish red.	27	10	281	3.55	1000
2	Weissenborn, Gotha.	Yellowish red to red brown.	66	9	300?	3.60	1080
3	Vockrodt, Mülhausen.	Light red to brown.	23	—	300?	3.33	999
4	Packe, Neustadt.	Light red to dark red.	33	12	300?	3.50	1050
5	Scholz, Dürgoy.	"	24	9	300?	3.64	1092
6	Rossbach, Planen.	"	47	18	300?	3.50	1050
7	Möller, Elmshorn.	Dark red to blackish.	19	—	—	2.42	—
8	Köhler, Aalsgard.	Light red to dark red.	25	8	—	2.50	—
		(*b*) For Bohemian Lignite					
1	Hüpeden, Mengelsdorf.	Light red to dark brown.	25	9	300?	3.76	1128
2	Ephraim, Pillnitz.	Light red to dark red.	63	24	352	3.75	1320
3	Waltersdorf Actien-Gesellschaft.	Light red to red-brown.	30	12	300?	3.50	1050
		(*c*) For Earthy Lignite					
–	——	——	—	—	—	—	—
		Tunnel Kiln Burning Loam. (*a*) For Bituminous Coal					
1	Fickentscher, Zwickau.	Light red to dark red.	96	—	300?	3.30	999

CONTINUOUS KILNS

E. Kilns for Loams

(*a*) For Bituminous Coal Firing

Series number.	Weight per hektoliter of coal. Kilograms.	Cost per hektoliter of coal. Pfennigs.	Weight of coal.		Cost of coal.		Hand or machine. Soft or stiff mud.	Setting. Dry or damp	Building brick, paving brick, or face-brick.
			Per cubic meter of kiln space. Kilograms.	Per 100 kilograms of clay-ware. Kilograms.	Per cubic meter of kiln space. Pfennigs.	Per 1000 bricks Pfennigs.			
1	38	34	42	4.2	38	135	Hand, soft mud. Machine, stiff mud.	Damp.	Building brick.
2	70	119	60	5.6	102	340	Hand, soft mud.	"	"
3	—	80 per cwt.	75	7.5	120	400	—	—	"
4	—	35 per cwt.	54	5.1	38	127	—	—	"
5	—	50 per cwt.	51	4.7	51	170	—	—	"
6	70	70	68	6.5	68	200	Hand, soft mud.	Damp.	"
7	—	275 per cwt.	—	—	—	285	—	—	"
8	—	113 per cwt.	—	—	—	290	—	—	"
		Average 58							

(*b*) For Bohemian Lignite

1	63	61	75	6.7	73	243?	—	—	Face-brick and building brick.
2	60	33	62	4.7	34	97	Machine, stiff mud.	Seldom damp.	Building brick.
3	77	55	77	7.3	55	183	Hand.	—	Hard burnt.
		Average 71							

(*c*) For Earthy Lignite

—	—	—	—	—	—	—	—	—	—

Tunnel Kiln Burning Loam. (*a*) For Bituminous Coal Fuel

—	73	57	57	5.7	45	150	Machine.	Barely dry.	Building brick.

CONTINUOUS KILNS

E. KILNS FOR LOAMS

(*a*) For Bituminous Coal Firing

Series number.	Accessory charge.	Size of brick.	Per cent of rejected material.	Firing periods. Minutes.	Use of waste heat.	Cycle of the kiln. Days.	Remarks.
1	None.	Standard.	—	7–10	None	11–12	Coal used as dust screenings.
2	Roofing tile, pipes and slabs.	"	5	7–10	None.	10	
3	Roofing tile, lime and gypsum.	"	—	—	Water-smoking.	—	
4	Pipes and roofing tile.	"	—	—	"	—	
5	Roofing tile.	"	—	—	"	—	
6	None.	"	1–2	5	None.	12–14	
7	—	Hamburg size.	—	—	None.	—	Nut-lignite with bituminous coal dust.
8	—	"	—	—	Water-smoking.	—	
				(*b*) For Bohemian Lignite			
1	Roofing tile.	Standard.	—	—	Water-smoking.	—	
2	Roofing tile, hollow brick and porous brick.	"	5	20	None.	16–18	
3	—	"	$1^1/_4$–$1^1/_2$	5	Drying.	14	
				(*c*) For Earthy Lignite			
	—	—	—	—	—	—	
			Tunnel Kiln Burning Loam.	(*a*) For Bituminous Coal			
1	Nothing.	Standard.	$^3/_4$	—	Drying.	—	Generator with step and horizontal grates, 2 men firing, day and night.

PERIODIC KILNS

(*a*) SEMI-CONTINUOUS KILNS

Series number.	Name of the brick works.	Color of the burnt clay.	Size of the kiln chamber. Cubic meters.	Number of fireplaces.	Kind of furnaces.	Dimensions of fireplaces.	Weight of one brick. Kilograms.	Number of bricks per cubic meter of kiln space.
1	Dr. Cohn Splau Clay Works.	Yellowish white to leather-brown.	109	3	Flat grates and hand-firing.	0.9 sq. meter.	4.00	300 ?
2	Später, Pretsch.	Yellowish red to brown.	156	3	"	0.96 sq. meter.	3.50	300 ?
3	Vockrodt, Mülhausen.	Red to brown.	28	3	"	—	3.33	300 ?

(*b*) CASSEL KILNS

1	Peters, Vorsfelde.	Light red to dark red.	108	3	Flat grates.	1.28 sq. meter.	3.70	300 ?
2	Ewerbeck, Brake.	Yellow to brick-red.	41	3	"	1.2 " "	4.00	300 ?
3	Gottschalk, Ammendorf.	Flesh-red to light yellow.	90	—	"	—	3.50	300 ?
4	Meisel, Muldenstein.	Yellow to leather-brown.	108	—	—	—	2.25	300 ?

(*c*) SQUARE DOWN-DRAFT KILNS

1	Schaaf, Halle.	Yellow to dark red.	42	2	Flat grates.	0.5 broad. 1.0 deep. 0.45 high.	3.30	360
2	Kiesler, Grünberg.	Light red to dark red or black.	67	5	Partial grates.	0.47: 1.77.	3.90	300 ?
3	Wustemann, Welkau.	——	—	—	—	—	—	300 ?
4	Nicolai, Freiberg.	——	—	—	—	—	—	300 ?
5	Hagenah, Stade.	Dirty red.	51	—	—	—	2.25	—
6	Rohrmau, Muskau.	Yellow to dark green.	42	3	—	0.42	Chemical utensils.	—

(*d*) ROUND DOWN-DRAFT KILNS

1	March Charlottenburg.	Chamois to gray.	27	—	Pulpit with vertical chamotte checker-work in place of grates.	0.32 broad. 0.65 deep. 0.85 high.	Chemical receptacles.	—
2	"	Yellow to leather-brown.	50	8	"	0.32 broad. 0.75 deep. 0.85 high.	4.37	330

PERIODIC KILNS

(*a*) SEMI-CONTINUOUS KILNS

Series number.	Weight of a cubic meter of kiln space. Kilograms.	Weight per hektoliter of coal. Kilograms.	Cost per hektoliter of coal. Pfennigs.	Weight of coal.		Cost of coal.		Hand or machine. Soft or stiff mud.	Setting. Dry or damp.	Building brick, paving brick, or face-brick.
				Per cubic meter of kiln space. Kilograms.	Per 100 kilograms of clay-wares. Kilograms.	Per cubic meter of kiln space. Pfennigs.	Per 1000 bricks. Pfennigs.			
1	1200	63	55	207	17.0	181	603	Machine, moderately soft.	Dry.	Face-brick.
2	1050	63	53	122	12.0	103	343	Hand.	—	Building brick.
3	999	—	80 per cwt.	140	14.0	224	747	——	—	"
(*b*) CASSEL KILNS										
1	1110	75	75	90	8.1	90	300	Hand.	—	Building brick.
2	1200	75?	120	243?	20.3	389	1300	—	—	"
3	1050	75	25	180	17.1	60	200	—	—	"
4	675	75	20	65	9.6	17	57	—	—	Porous brick.
(*c*) SQUARE DOWN-DRAFT KILNS										
1	1200	1000 coal briquettes each 1 kg.	10 marks per 1000.	309	25.8	309	858	Both.	Dry.	Face-brick and building brick.
2	1170	70	75?	383?	32.7	410	1367?	—	—	Building brick.
3	—	—	55 per cwt.	285	—	—	1000	—	—	"
4	—	—	51 per cwt.	225	—	—	765	—	—	—
5	—	88	95?	119	—	—	—	—	—	Building brick; only roofing tile.
6	—	—	89	86	—	—	—	—	Dry.	Pavers.
(*d*) ROUND DOWN-DRAFT KILNS										
1	—	75	160	181	—	386	—	—	Dry.	Pavers.
2	1442	75	160	258	17.9	550	1667	Mostly hand, rather stiff.	"	Face-brick and hard brick.

PERIODIC KILNS

(A) SEMI-CONTINUOUS KILNS

Series number.	Accessory charge.	Size of brick.	Per cent. of rejected material.	Firing periods. Minutes.	Use of the waste heat.	Duration of the burn.	Remarks.
1	Building ornaments, etc.	Face-brick standard.	—	—	Drying.	—	Lignite clays and Bohemian lignite.
2	Roofing-tile.	Standard.	—	—	—	—	Somewhat calcareous clay from the Elbe; Bohemian lignite.
3	"	"	—	—	—	—	Loam and bituminous coal.

(B) CASSEL KILNS

Series number.	Accessory charge.	Size of brick.	Per cent. of rejected material.	Firing periods. Minutes.	Use of the waste heat.	Duration of the burn.	Remarks.
1	Roofing tile, drains, etc.	Standard.	—	—	Drying.	—	Bituminous coal, a medium fat, ferruginous clay.
2	Sidewalk tiles, Floor tile.	"	—	—	"	—	Yellow clay, with white micaceous clay intermixed and bituminous coal.
3	Porous brick.	"	—	—	—	—	Lignite clays and earthy lignite.
4	—	"	—	—	Water-smoking.	—	"

(C) SQUARE DOWN-DRAFT KILNS

Series number.	Accessory charge.	Size of brick.	Per cent. of rejected material.	Firing periods. Minutes.	Use of the waste heat.	Duration of the burn.	Remarks.
1	—	Standard.	—	—	—	9 days.	Clay from the Saale, with Buntsand stein clays, somewhat calcareous and silty; earthy lignite.
2	Pipes, roofing-tile.	"	—	—	Water smoking.	—	Fat, marly loam, earthy lignite and bituminous coal.
3	—	—	—	—	—	—	Bohemian lignite (nut size).
4	—	—	—	—	—	—	"
5	—	Hamburg shape.	—	—	—	—	Clay from the Elbe and bituminous coal.
6	—	—	—	—	Drying.	—	Lignite clays and bit. coal.

(D) ROUND DOWN-DRAFT KILNS

Series number.	Accessory charge.	Size of brick.	Per cent. of rejected material.	Firing periods. Minutes.	Use of the waste heat.	Duration of the burn.	Remarks.
1	—	—	Almost nothing.	60 min. 2-3 shovels.	In the second story for burning ferruginous material and drying.	72 hours.	Lignite "bottle clay" and bituminous coal.
2	Terra cotta.	Face-brick standard.	"	30 min. 2 shovels.	Drying.	96 hours.	Lignite clay, with porcelain earth. Bituminous coal.

D. ROUND DOWN-DRAFT KILNS (*Continued*)

Series number.	Name of the brick works.	Color of the burnt clay.	Size of the kiln chambers. Cubic meters.	Number of fire-places.	Kind of furnaces.	Dimensions of fireplaces. Meters.	Weight of one brick. Kilograms.	Number of bricks per cubic meter of kiln space.
3	March, Charlottenburg.	Yellow to leather-brown	38	6	Shaft with vertical brick checker-work in place of grates.	0.32 broad. 0.65 deep. 0.86 high.	4.37	330
4	"	Red to brown,	38	6	"	"	4.11	330
5	Pechar, Teplitz.	White.	80	10	Step-grates.	0.6 broad. 0.59 deep. 0.97 high.	4.1–6.7	—
6	Rössler, Wächtersbach.	"	Biscuit, 100 Glost, 75	12 12	—	0.21 sq. m. 0.28 sq. m.	Stoneware.	—
E. ROUND UP-DRAFT KILN								
1	Rach, Oeynhausen.	Gray-brown.	43	8	Plane grates and inclined grates combined	0.45 broad. 0.60 deep. 0.60 high.	Stoneware like that of Höhr	—
F. OLD GERMAN KILNS WITH ARCHES								
1	Packe, Neustadt, O. S.	Light to dark red.	166	8	Flat grates.	0.66 sq. m.	3.50	300 ?
2	Scholtz, Dürgoy.	"	166	6	—	0.40 sq. m.	3.64	300 ?
3	Lorenz, Planen.		107	—	Simple grate.	—	4.25	300 ?
4	Lobien, Brand, i. S.	Light red to dark red.	90	—	Narrow grates.	—	3.58	300 ?
5	Füllner, Havelburg.	Light red to brown.	100	—	—	—	3.50	300 ?
6	Meisel, Muldenstein.	Yellow to leather-brown.	about 140	—	Grates.	0.90	4.00	300 ?
7	Schmidt, Schönau.	Light red to dark red.	121	—	—	0.34 broad. 5.50 deep. 0.75 high.	4.63	300 ?
G. OLD GERMAN KILNS WITHOUT ARCHES								
1	Böhme, Schewen.	Red.	85	4	—	0.34 broad. 3.70 deep. 0.32 high.	3.50	190 ?
2	Krieger, Karbowo.	Light red.	99 ?	4	—	0.36 broad. 5.89 deep. 0.43 high.	3.35	311
3	Weinschenk, Lulkau.	Yellowish red to reddish brown.	146	6	—	0.37 broad. 0.77 deep. 0.47 high.	3.25	300 ?

(D) ROUND DOWN-DRAFT KILNS (*Continued*)

Series number.	Weight of a cubic meter of kiln space. Kilograms.	Weight per hektoliter of coal. Kilograms.	Cost per hektoliter of coal. Pfennigs.	Weight of coal.		Cost of coal.		Hand or machine. Soft or stiff mud.	Setting. Dry or damp.	Building brick, paving brick, or fire-brick.
				Per cubic meter of kiln space. Kilograms.	Per 100 kilograms of clayware. Kilograms.	Per cubic meter of kiln space. Kilograms.	Per 1000 bricks. Pfennigs.			
3	1442	75	160	255	17.7 ?	544	1648	Mostly hand process; tolerably stiff.	Dry.	Face-brick and hard brick.
4	1356	75	160	128	9.4	273	827	"	"	"
5	1900?	60	100 kg. 12. Pf.	337	17.7 ?	40	—	Machine stiffened.	"	Hard bricks and refract'y bricks.
6	—	82	200	Biscuit 76 Glost 61	—	Bisci't 125 Glost 150	—	—	"	Whiteware, 30 per cent.
(E) ROUND UP-DRAFT KILN										
1	—	75	86	105	—	120	—	—	Dry.	Pavers.
(F) OLD GERMAN KILNS WITH ARCHES										
1	1050	——	35 per cwt.	90	9.0	63	210	——	——	Building brick.
2	1092	——	50? per cwt.	120	11.0	120	400	——	——	"
3	1275	100	130	150	11.8	195	650	——	——	"
4	1074	80	99	144	13.4	178	593	——	——	"
5	1050	63	68	211	20.1	228	760	——	——	"
6	1200	75	20	380	31.7	101	337	——	——	Bldg br'k & pavers.
7	1389	90 kg. coal 1 cu. m. peat 350 kg.	102 per cu. m.	83 coal. 1 cu. m. wood. 0.06 cu. m. turf.	6.0?	169	563?	Hand.	Dry.	"
(G) OLD GERMAN KILNS WITHOUT ARCHES										
1	—	Wood. 325 kg. per cu. m.	500 per cubic m.	286	—	410	—	Hand.	Barely dry.	"
2	1042	Wood per cubic meter. 325 kg. 1 cu. m turf. 310 kg.	500 per cubic m. 185	170 78	— —	262 47	842 151	"	Dry.	"
3	975	Wood per cubic meter. 325 kg.	525 per cubic m.	Wood 156	16.0	252	840	"	—	Building brick.

(D) ROUND DOWN-DRAFT KILNS (*Continued*)

Series number.	Accessory charge.	Size of bricks. Centimeters.	Per cent of rejected material.	Firing-periods. Minutes.	Use of the waste heat.	Duration of the burn. Hours.	Remarks.
3	Terra cotta. 25 : 75	Standard face-brick size.	Almost nothing.	30 min. 2 shovelfuls.	Drying.	96 hours.	Lignite clays with porcelain earth and bituminous coal.
4	Setting tiles. 5 : 95	"	"	20 min. $1^1/_2$ shovelfuls.	"	72 hours.	Ferruginous river clay, Rathenow clay and bituminous clay.
5	Gas retorts, mosaic tiles, etc.	31 : 15.5 :: 8 26.5 : 13.0 :: 8 25 : 12.5 :: 6.5	2	60 min. with 25 kilograms high fire.	"	110 hours.	Refractory lignite clay and Bohemian lignite.
6	70 per cent setting tiles.	—	—	—	Not used.	—	Lignite clay, with kaolin, flint, and feldspar; bituminous coal.
				(E) ROUND UP-DRAFT KILN			
1	—	—	—	—	—	168	Rhine clays, bituminous coal, round porcelain kilns.
				(F) OLD GERMAN KILNS WITH ARCHES			
1	Pipes and roofing tiles.	Standard.	—	—	Water-smoking.	—	Mild loam, bituminous coal.
2	Nothing.	"	—	—	—	—	Lean loam, bituminous coal.
3	—	"	—	—	Not used.	—	Loam, bituminous coal.
4	—	"	—	—	—	—	Fat loam, bituminous coal.
5	Roofing tile.	"	—	—	—	—	Clay from the Elbe and calcareous clay; lignite and some wood.
6	Hollow brick, shaped brick, and fire-brick; floor tile.	"	—	—	—	—	Lignite clay with kaolin; earthy lignite fuel.
7	Roofing tile.	29 : 13 : 6	$3^2/_3$	—	Not used.	192	Calcareous, fat, lignite clay; (loam) kiln-arched, with ducts accord. to Conrad's patent, D. R. P., 14,929.
				(G) OLD GERMAN KILNS WITHOUT ARCHES			
1	Roofing tile and drain tile.	Standard.	1–2	—	—	144	Fat loam, with wood; ducts as above.
2	"	"	$^3/_4$	—	Not used.	144 to 168	Silty, fat, calcareous clay; ducts as above.
3	—	"	3–4	—	—	144	Ferruginous loam and wood fuel; ducts as above.

NOTE: I kilogram = 2.2 pounds. I hektoliter = 0.1 cubic meter = 2.84 bushels. 1 cubic meter = 1.308 cubic yards. 1 meter = 100 centimeters = 39.37 inches. 1 cwt. = 100 Germ. pounds = 110 pounds (English). 1 mark = 100 pfennigs = $0.24.

Mechanical Examination of a Brick-Clay

PROF. EDWARD ORTON, JR., TRANSLATOR

The clay tested came from the neighborhood of Neckermuende (Western Pommerania), and is particularly distinguished by its exceptional sensitiveness to rapid drying, sun or drafts, so that even when handled with the greatest care it gives rise to a high percentage of waste, in spite of the fact that it was rendered leaner by the addition of one-third of sand before use. Proceeding with the view that this disagreeable property of the material had its cause in some purely physical phenomena and that the chemical composition must be without influence, since the same trouble occurs in clays of the most diverse composition, the chemical examination was entirely neglected, and only a mechanical separation of the ingredients of the clay was undertaken in order to see to which constituent can be attributed the property which makes the clay so difficult to work. There were on hand two samples taken from the same location: the one, I, freshly dug from the pit; the other, II, exposed to weathering for one winter.

Clay I appears to be a solid, tough and rather stiff mass cutting smoothly with the knife, without indicating the presence of sand, small stones or other impurities.

Clay II has been thoroughly opened up by the freezing; it was uniformly saturated with water, fat and slippery; on being cut it showed a considerable quantity of small needle-like gypsum crystals.

In the mechanical analysis, the subdivision of the body, according to the size of the grains, was performed by the Schoene apparatus, so that the clay, after it was dried, was boiled with water for two hours, in order to loosen the clay from the non-plastic ingredients (sand). The clay was then decanted off, and the sand again boiled and returned to the washing funnel.

The current-velocities used were so regulated that, accepting the current conceptions on the subject, grains up to 0.01 mm.

diameter were washed off as clay, silt from 0.01 to 0.02 mm., dust sand from 0.02 to 0.04 mm., fine sand 0.04 to 0.2 mm., and coarse sand over 0.2 mm.

The following was found to be the composition of the clays:

Names of grades.	Diameter of grains. mm.	Clay No. I. Per cent.	Clay No. II. Per cent.
Clay substance, - - -	0.0 to 0.01	71.9	73.6
Silt, - - - -	0.01 to 0.02	5.6	2.3
Dust sand, - - - -	0.02 to 0.04	4.0	3.7
Fine sand, - - -	0.04 to 0.20	18.3	18.7
Coarse sand (and gypsum), -	0.20 and above	0.2	1.7
Totals, - - -		100.0	100.0

The bonding power of each clay is from 6 to 7. It can be seen that, apart from the presence of gypsum in some parts of the deposit, the two samples are very much alike, and consist practically of a mixture of clay substance with about one-quarter of fine sand, while coarse sand is practically absent.

A closer study of the properties of the separate ingredients of the clays enables us easily to recognize their behavior in drying, and also gives opportunity to draw direct conclusions from the mechanical analyses as to the properties of the raw materials, by taking into consideration the properties of the non-plastic materials which have been obtained from them.

The natural non-plastics of a clay, in by far the most cases, consist of sand; *i. e.*, ground mineral detritus of any sort, very generally quartz. These show perceptibly different qualities than those which we observe in the cases of clays inclined to cracking.

If we allow dampened quartz sand of any size of grain, even that which is washed out in a mechanical analysis as silt, dust sand, fine sand and coarse sand, to dry out, we get a body without cohesion, in which we can recognize no trace of adhesive strength. When wet, they do not swell up, as clays do, but simply absorb water until full. The non-plastic material obtained from the clay of Ueckermünde behaves differently; it dries, as ordinary sand does, to a soft mass without noticeable cohesion but shows a very considerable shrinkage in such a way that a sample dried upon a watch-glass disrupts in all directions and seems penetrated by a network of cracks. The clay, freed from its non-plastic materials, dried down to a slightly-cracked, strongly-warped slab; the cracks in the sands seemed broader in proportion as the sand became coarser, and therefore were most pronounced in the "fine sand" grade, which was also present in larger quantity than any of the other non-plastic substances.

A sample of this fine sand was made up with water to a plastic dough, a little slab was fashioned from it, and its shrinkage in drying measured. The reduction in length amounted to 11.5 per cent which is as much as we find in fat clays, while in sands consisting of quartz detritus, the shrinkage is nothing. On dampening, this sand obtained from the clay swells up considerably, feels soft, and coheres noticeably after rubbing and kneading. Under the microscope, it appears very different from that which we usually consider as sand. It is not composed of separate splintered or rounded mineral grains, but of masses of small clay and dust particles, which are stuck together in little grains by some binding material.

It is clear that a non-plastic material of such different qualities from clay is in position to impart very unusual characteristics. Quartz sand, when added in certain proportions, reduces the cohesion of a clay, because it undergoes no shrinkage during the drying process. A non-plastic of the above-described properties is able to increase the shrinkage of the pure clay-substance, since it shrinks very strongly itself. And, since it does not possess the property of drying out to a hard mass itself, it weakens at once to cohesion of the clay, and gives rise to more pronounced cracking than pure clay without this admixture would do.

This investigation teaches as its lesson that not every sand, whether present naturally in the clay, or added artificially in its preparation, possesses the properties which enable it to improve the qualities of the clay in any given direction. Under some circumstances, it may accomplish just the reverse; indeed, in many cases, the clay may derive from it the very properties which make it harder to work. It therefore seems imperative that we give special consideration to the properties of sand as the one ingredient never absent from the raw material, and generally making its greatest single part. Hence, where an artificial addition of sand is necessary, one should make a proper selection or should palliate the influence of sand naturally present by other suitable additions (marl for instance).

Investigations of Materials for the Brick and Pottery Industries

(Prepared from the records of the Royal Porcelain Manufactory)

PROF. EDWARD ORTON, JR., TRANSLATOR

I. CLAY FROM CARLSBURG (CONVENT LOCCUM)

The mechanical analysis of the potter's clay and the brick-clay gave the following results:

	mm.	Pottery clay. Per cent.	Brick clay. Per cent.
Coarse sand, - -	above 0.2 diameter of grain	3.7	2.3
Blotting sand, -	0.2 to 0.05	14.9	11.7
Dust sand, - -	0.05 to 0.02	15.4	16.6
Silt, - - -	0.02 to 0.01	6.5	14.8
Clay substance, - -	finer than 0.01	59.5	54.6
		100.0	100.0

The product over 0.2 mm. diameter of grain, obtained by washing, consisted of larger or smaller grains of marl in the pottery clay; in the brick-clay the grains consisted only of sand.

For the making of stove-tiles, and common faience, for which the clay is sufficiently plastic, it must be subjected to a washing process, since the marl grains (consisting of calcium carbonate) enclosed in the ware made from unwashed clay, would not burn dead at the temperatures used in burning common pottery, and would occasion spalling of the body when the ware came in contact with water.

The brick-clay is less plastic, though it would also be suitable for the production of pottery products, so far as composition is concerned.

The rational analyses of the materials showed:

Ingredients.	Pottery clay. Per cent.	Brick clay. Per cent.
Calcium carbonate,	20.09	22.30
Clay substance,	64.80	59.64
Quartz,	6.95	5.03
Feldspar,	8.16	13.03
	100.00	100.00

In order to stop the tendency of the glazes used on these pottery wares to craze, it will be necessary, to plunge in so much chalk, or marl, as will bring up the calcium carbonate content to that of the Velten clay, 25 to 30 per cent.

The brick-clay is only suited for the manufacture of common bricks on account of its considerable content of calcium carbonate.

2. CLAY FROM PUCHAU

	Per cent.
SiO_2,	69.25
Al_2O_3,	15.56
Fe_2O_3,	5.62
CaO,	0.45
K_2O,	4.16
H_2O,	4.97
	100.00

This clay is used for the manufacture of brick products. In order to burn a brown-black glaze on it, the following series of glaze batches, growing more infusible was used:

Glaze melting at cone No. 1.	Parts.
Clay from Puchau,	100.0
Powdered glass,	34.0
Chalk,	28.5
Iron oxide (*Caput Mortuum*),	10.5
Total,	172.5

By addition of about 4 per cent of manganese and copper oxide, the brown glaze becomes deep black.

Glazes melting at cone No. 05.	Parts.	Parts.
Clay from Puchau,	100.00	100.00
Chalk,	10.00	25.00
Red lead,	57.00	—
Oxide of manganese,	8.00	—
Glass powder,	—	34.00
Caustic lime,	—	3.5
Hydrous boracic acid,	—	7.0
Iron oxide (*Caput Mortuum*),	—	12.0
Totals,	175.00	181.5

In order to color the last glaze darker, 0.5 to 1 per cent of chrome oxide, or in place of the latter 0.75 to 1.5 per cent of chrome iron ore must be added. In the middle glaze, the tendency to crazing will be lessened, if the quantity of manganese is increased at the expense of the red lead, by reckoning 40 parts of manganese oxide equal to 115 parts of red lead. If instead of 57 parts of red lead, only 57 less 11.5 = 45.5 parts are taken, the manganese must be increased to 12 parts. By this change, the glaze will become somewhat less fusible.

3. BRICK-CLAY FROM WICKENDORF NEAR SCHWERIN

On washing this on a sieve of 900 meshes per square centimeter (about 75 inches per lineal inch), a residue of 3.6 per cent consisting mostly of pieces of lime was left, which ought to be removed by a washing process. The washed clay contained:

	Per cent.
SiO_2,	52.99
Al_2O_3,	13.65
Fe_2O_3,	4.60
CaO,	10.30
MgO,	2.32
Na_2O,	3.60
Loss on ignition,	12.52
	99.98

On burning in a reducing flame up to cone 05, the clay takes on a yellow color.

4. BRICK-CLAY FROM HELMSTEDT

The chemical analysis gave the following composition:

	Per cent.
SiO_2, - - - - - -	73.20
Al_2O_3, - - - - -	18.89
Fe_2O_3, - - - - - -	4.26
CaO, - - - - - -	2.87
MgO, - - - - - -	1.40
K_2O, - - - - - -	1.05
Loss on ignition, - - - -	6.33

The wares made from this clay are burnt between cones Nos. 010 and 05, and at that temperature take on a bright or darker red color. Since it was desired to provide part of this product with a red-brown glaze at the same burning temperature, the melting-point of the glaze had to mature at the same temperature. The compounding of the glaze should, if possible, be accomplished only by the addition of red lead to the clay, which in this case can be carried out without difficulty.

Deducing the molecular composition of the clay, from the percentage composition as given, by dividing the various constituents by the molecular weights, we obtain the following proportions:

	Percentage composition.	Molecular weight.	Molecular composition.	
SiO_2, - -	74.20 divided by	60 equals	1.22	SiO_2
Al_2O_3, -	18.89 " "	103 "	0.105	Al_2O_3, (Fe_2O_3)
Fe_2O_3, - -	4.26 " "	160 "	0.025	
CaO, - -	2.87 " "	56 "	0.050	CaO, MgO, K_2O
MgO, - -	1.40 " "	40 "	0.035	
K_2O, - -	1.05 " "	94 "	0.010	

Now, by experience we know that we will obtain an easily fusible and sufficiently weather-resisting glaze, if the various ingredients are grouped in the following molecular proportions:

$$0.8\ PbO : 0.2 \left\{ \begin{array}{l} K_2O \\ CaO \\ MgO \end{array} \right. : 0.3\text{–}0.4 \left\{ \begin{array}{l} Al_2O_3 \\ \\ Fe_2O_3 \end{array} \right. : 2.50\ SiO_2$$

Since in the present instance, the proportions of the clay are approximately

$$0.2\left\{\begin{matrix}K_2O\\ CaO\\ MgO\end{matrix}\right. : 0.26\left\{\begin{matrix}Al_2O_3\\ \\ Fe_2O_3\end{matrix}\right. : 2.50\ SiO_2,$$

it follows that the above glaze may be made without further trouble, by merely adding 0.1 molecule of lead oxide, and 0.1 molecule of ferric oxide to the clay. By so doing, we will obtain a glaze of the composition:

$$\left.\begin{matrix}0.8\ PbO\\ 0.2\ K_2O\end{matrix}\right\} 0.36\ Al_2O_3\ (Fe_2O_3)\ 2.50\ SiO_2.$$

Or, in parts by weight:

	Parts.
Raw Helmstedt clay,	200
Lead oxide (red lead or minium),	182
Ferric oxide (English red or *Caput Mortuum*),	18

or:

	Parts.
Burnt Helmstedt clay,	188
Lead oxide,	182
English red,	18

If we wish to make the glaze darker, 0.1 molecule of manganese oxide should be added, and the glaze batch becomes:

	Parts.
Red Helmstedt clay,	200
Lead oxide,	182
English red,	16
Manganese ore,	18

On glazing ware in the leather-hard condition, it is best to add some sort of adhesive substance to the glaze (dextrin, oxblood, and the like) in order to avoid the shelling off of the glaze layer from the wares after drying.

5. CLAY FROM FÖRDERSTEDT, NEAR SCHOENEBECK

	Per cent.
Clay substance,	88.88
Quartz,	10.46
Feldspar,	0.66
	100.00

	Per cent.
SiO_2,	52.55
TiO_2,	0.37
Al_2O_3,	28.26
Fe_2O_3	3.46
CaO,	trace
MgO,	1.49
Alkalies,	4.12
Loss on ignition,	9.40
H_2SO_4,	0.27
	99.92

Since the clay contains concretions of iron pyrites sprinkled through it, the sulphuric acid found combined with the bases has arisen from the weathering of this pyrite. For practical use, the latter must be washed out, in order to guard against discoloration on the surface of the ware. Owing to its considerable content of ferric oxide, the clay burns to a yellow color, with the above ratio between the iron oxide and the alumina, but it shows considerable shrinkage. It is therefore necessary to mix this very fat and easily warped material with non-plastic material.

A mixture of clay (60 parts) and sand (40 parts) shows, in the air-dry condition, a linear shrinkage of 3 per cent and in the biscuit condition, 6.33 per cent. Besides for the manufacture of face-brick, this material is suited for the manufacture of sewer-pipes and conduits, since it is sufficiently refractory to endure salt-glazing. Since the clay is extraordinarily fine-grained, and contains no coarse sandy matter, it may be used for the manufacture of Portland cement, by blunging into it the necessary quantities of either chalk or marl.

6. CLAYS FROM HAINSTEDT

The chemical analysis of these clays gave the following results:

	Clay No. 1 (sandy). Per cent.	Clay No. 2 (fat). Per cent.
Clay substance,	32.52	63.92
Quartz,	67.03	35.56
Feldspar,	0.45	0.52
Total,	100.00	100.00

	Per cent.	Per cent.
SiO_2,	83.30	67.45
Al_2O_3,	10.33	23.22
Fe_2O_3,	0.89	1.19
CaO,	trace	0.98
MgO,	—	trace
K_2O,	0.46	0.51
Loss on ignition,	3.20	6.72
Total,	100.18	100.07

With respect to the temperatures used in the brick industries, the clays are rather refractory. The sandy clay does not become dense in the porcelain kiln, but the fat clay vitrifies at this temperature. Both clays burn to a light yellow-brown color, and for the manufacture of bricks are best mixed with each other.

Face-brick can be made by addition of feldspar to No. 1, and of sand and feldspar or a suitable feldspathic sand to No. 2, which will be of a porcelain-like or vitrified character, and whose content in clay substance, quartz and feldspar will correspond to the following proportion:

	Per cent.
Clay substance,	25
Quartz,	40
Feldspar,	30

Using clays No. 1, and No. 2, and pure feldspar and sand, the following mixtures would be required to make the above composition:

	Parts.
Clay No. 1, lean,	70.5
Feldspar,	29.5
Total,	100.0

	Parts.
Clay No. 2, fat,	40.0
Sand,	30.5
Feldspar,	29.5
Total,	100.0

The products, when burned to vitrification, are perfectly impervious to the attacks of the weather. They attain the porcelain-like character, on burning at cone Nos. 8 to 10, and bear the colored glazes used on Seger-porcelain without crazing.

7. CLAYS FROM THE EIFEL

The materials designated according to their appearance in the moist condition as red (1), green (2), gray (3), yellow (4), and brown (5) clay, owe their appearance to the quantity and to the coarser or finer subdivision of the iron oxide and hydroxide, to the state of oxidation in which the oxides occur, and to the small quantities of organic substances which are contained in them. The clays form porous, very slightly plastic bodies, and part of the colors alter on drying; cones Nos. 2, 3, and 4, for example, approximate the color of ochre so very closely that it would be very difficult to make a practical use of the difference in color. In order to use these clays as paint colors, a washing process would be sufficient.

The investigation as to whether the clays could be used in the manufacture of brick and tile-products, was carried at once to the burning tests, which were performed with little briquettes molded from the clays at the temperature of from cone No. 010 to No. 05. From these tests, it was found that at these temperatures, which are generally applied in the burning of bricks and tile, these clays attained no satisfactory degree of density. No distinction in the burnt color was discernible in the five different materials. At the melting-point of cone No. 4, the clays vitrify with considerable shrinkage, amounting to the following values:

Clay No. 1,	- - - -	12.4 per cent linear shrinkage.
Clay No. 2,	- - - -	12.8 " " "
Clay No. 3,	- - - -	14.2 " " "
Clay No. 4,	- - - -	16.7 " " "
Clay No. 5,	- - - -	9.3 " " "

When burnt to this point, the material would seem suited to the manufacture of paving bricks, if they did not dry out in the raw condition to such a tender mass that the transportation from the dryer to the kiln would be exceedingly difficult. I order to give the clays the necessary durability in the dry condition, an addition of very plastic fat clay would be necessary.

Mixtures of 4 parts by weight of the above clay and one part of the Eberhahn clay, molded up into little test bricks, showed sufficient strength in the dry condition, and when burnt at the temperature of cone No. 05 could be used as face-brick. At cone No. 4 they vitrified, but with less inclination to warping than in the unmixed-clay tests; their shrinkage amounted to 12 per cent, 11.8 per cent, 11.8 per cent, 13.5 per cent, and 9.5 per cent respectively. Since the shrinkage is still very considerable, the partial replacement of the unburned ochre by burnt waste should be taken into consideration.

The chemical examination of clays Nos. 2 and 5 gave the following result:

	Clay No. 2. Per cent.	Clay No. 5. Per cent.
SiO_2,	61.76	74.81
TiO_2,	0.23	0.37
Al_2O_3,	17.80	13.20
Fe_2O_3,	10.40	5.87
CaO,	trace	trace
MgO,	0.95	0.44
K_2O,	3.52	2.29
Loss on ignition,	5.14	3.39
Total,	99.80	100.37

8. INVESTIGATION OF A TIN-GLAZE FOR STOVE TILES

The analysis of the fused glaze gave the following results:

	Per cent.
SiO_2,	44.96
SnO_2,	15.66
PbO,	26.92
Al_2O_3,	5.12
CaO,	0.51
MgO,	0.23
Na_2O,	6.11
Total,	99.51

In order to find an expression for the molecular composition of the glaze from the percentage composition obtained by chemical analysis, the weight of each substance was divided by its molecular weight, and the following ratios calculated:

	Percentage composition.	Molecular weight.	Molecular composition.
SiO_2, - . -	44.96 divided by	60 equals	0.749 SiO_2
SnO_2, -	15.66 " "	150 "	0.104 SnO_2
PbO, - -	26.92 " "	223 "	0.121 PbO
Al_2O_3, -	5.12 " "	103 "	0.050 Al_2O_3
CaO, - -	0.51 " "	56 "	0.009 CaO
MgO, -	0.23 " "	40 "	0.005 MgO
Na_2O, - -	6.11 " "	62 "	0.099 Na_2O

If we add the lime and magnesia, which are present in the glaze merely as impurities, to the alkali, and take the fluxes (alkali and lead oxide) as unity, we will obtain the following molecular proportion for the composition of the glaze:

$$\left.\begin{matrix} 0.45\ Na_2O \\ 0.55\ PbO \end{matrix}\right\} 0.2\ Al_2O_3,\ 3.2\ SiO_2,\ 0.44\ SnO_2.$$

Calculated in batch weights of the separate ingredients, we will obtain a glaze of the above formula, by fritting together the following materials weighed dry:

0.45 Na_2O	corresponds to	47.70	parts of	calcined soda.
0.55 PbO	" "	122.65	" "	red lead.
$\left.\begin{matrix} 0.20\ Al_2O_3 \\ 0.40\ SiO_2 \\ 0.40\ H_2O \end{matrix}\right\}$	" "	51.80	" "	raw Zettlitz kaolin or washed china clay.
2.80 SiO_2	" "	168.00	" "	sand from Hohenbocka.
0.44 SnO_2	" "	66.00	" "	tin oxide.

Instead of introducing tin oxide and red lead as such, we can use tin-ash made by roasting the requisite quantities of lead and tin together; this has the advantage that the tin oxide is already in the finest state of subdivision in the tin-ash. In this instance, the tin-ash would be made of 114 parts of lead and 52 parts of tin, and instead of the red lead and the tin oxide, we would take 188.65 parts of the tin-ash for the glaze-batch.

If we desire to transform this glaze to a transparent one, we must leave out the tin oxide. If the glaze is too difficultly fusible, we can drop down the sand content to 120 parts, or fuse with this sand 37 parts of crystallized boracic acid.

9. Glaze for the Velten Clay

A black glaze for the Velten clay was made by fritting together:

Ferric oxide,	5 parts	2.5 parts iron oxide. or 7.5 chromite.
Chrome oxide,	5 "	
Cobalt oxide,	2 "	
Potassium nitrate,	10 "	
Red lead,	40 "	
Sand,	40 "	

By the reduction of the sand, and the increase of the lead content, the glaze can be made more easily fusible, and by a reverse process more infusible.

10. Examination and Preparation of a Smalt

The composition of the smalt was found to be:

	Per cent.
SiO_2,	67.51
Al_2O_3,	0.17
Fe_2O_3,	0.66
CoO,	7.07
CaO,	0.27
MgO,	0.26
K_2O,	14.72
As_2O_5,	9.41

We must consider the Al_2O_3, Fe_2O_3, CaO, and MgO as impurities or accidental constituents. If we omit the arsenic acid on account of its poisonous qualities, and substitute for cobalt oxide an equivalent quantity of lime for the preparation of a colorless glass, we will obtain a glass which is made by fusing:

	Parts by weight.
Quartz sand,	67.5
Potassium nitrate,	31.6
Calculated spar (chalk or marble),	11.0

If necessary, the arsenic acid, corresponding to 8.1 parts of arsenic, is to be added. The amount of cobalt necessary must be established by a series of trials.

11. The Cause of the Destruction of the Zinc Trimmings of a Berlin Market-House

On the inspection of the building it was developed that the zinc trimmings had been attacked and were partly eaten through in holes where they came in direct contact with the brickwork, giving rise to the formation of a whitish body. This was especially the case on the corners of the wall, where the sheet zinc was bent over upon the brick, while in those places where a small space was left between the zinc and the bricks, no noteworthy attack of the zinc had taken place. This was proved by cutting the zinc sheeting in different places, where holes could be seen from above. It was further observed that the attack was occasioned on those bricks which showed a strong efflorescence of salts, or "saltpeter," while on bricks which showed none of this efflorescence, no important attack of the zinc was occasioned.

The cause of this attack was developed by a close investigation, which was based upon the examination of:

(1) A face-brick of the kind used in the construction taken from a pile of bricks left over.

(2) A number of pieces of brick broken out from the wall in question, at the points at which the zinc sheeting had been eaten through. These all showed a strong efflorescence of the so-called "saltpeter" or scum.

(3) The white powder, which had arisen from the destruction of the zinc, and which was scratched off from the zinc sheets, taken from the spots where holes had been eaten through.

(1) The portion of the face-brick which could be extracted by water had a total weight of 0.91 per cent. This material, dried at 120° C., contained:

	Per cent.
Calcium oxide, - - - - -	35.75
Magnesia, - - - - -	3.08
Alkalies, - - - - - -	1.43
Sulphuric acid, - - - -	48.39
Chlorine, - - - - -	1.12
Alumina, - - - - -	trace
Water and carbonic acid, - - -	10.23
Total, - - - - -	100.00

This aqueous extract reacted neutral; it consisted principally of sulphates of lime (gypsum), magnesia, and the alkalies, chlorides of magnesium, and carbonate of lime and magnesia, all salts from which, on account of their neutral reaction, no attack on the zinc would be expected.

(2) From the pieces cut out, fragments strongly coated with the efflorescence were tested, and there was found in two tests, soluble matter of 1.62 and 1.86 per cent respectively. This efflorescence likewise reacted neutral; the quantity of the soluble ingredients is here very considerable. In good face-brick, soluble salts must not be present, or at least must be very slight in amount, and should never exceed 0.1 or 0.2 per cent.

The composition of this aqueous extract was:

	Per cent.
Calcium oxide,	26.39
Magnesia,	trace
Alkalies,	26.73
Sulphuric acid,	37.65
Chlorine,	1.65
Silica and alumina,	2.89
Water and carbonic acid,	4.95
Total,	100.00

(3) The white powder originating in the decomposition of the zinc contained:

	Per cent.
Zinc oxide,	60.75
Alumina and iron,	1.34
Calcium oxide,	1.41
Sulphuric acid,	14.62
Chlorine,	0.28
Water and carbonic acid,	13.29
Sand and brick dust,	9.06
Total,	100.75

According to these results it must be assumed that this phenomenon is caused by the oxidation of the zinc to zinc oxide, and that the proportionately small quantities of lime, sulphuric acid and chlorine have been introduced by infiltration from the parts of the brick in actual contact, which contain these substances in their efflorescence. It may be assumed that the oxidation of the zinc in these places, in distinction from the other portions of the zinc sheeting is brought about by the salts which come from the brick, and which are partly deliquescent in the air, thus keeping the metal always wet. The action of water, which is undoubtedly present, would be increased by the fact that the zinc takes a high temperature from the sun's heat, but does not dry out between the zinc and the bricks, which in the building are kept damp in the upper stories by the exhalations from below. It is also known that an energetic destruction of the zinc follows the driving of iron nails in it in the presence of moisture, but attention was never directed to the damp spots remaining on the surface of the zinc.

In order to test the behavior of similar salt mixtures on zinc and gypsum, to which about 5 per cent of magnesium chloride was added, in one case, and in another a mixture of about 50 per cent gypsum, 45 per cent sodium carbonate, and 5 per cent of common salt, corresponding about to the composition of the salts efflorescing from the bricks, was applied to the sheet zinc about 0.5 mm. thick and placed under a bell-jar sealed with water, and therefore in a saturated atmosphere. After a period of two months' action, these layers were removed by brushing under water. An earlier attack of the zinc resulted on those parts covered by the mixtures of the salts than on the pure metal. Under the magnifying glass, the places which were covered by the salts appeared rough and eaten into holes, while the spots not painted with the salts, had in general remained unaltered.

It therefore seems, in fact, that efflorescences of salts contained in bricks in comparatively large amounts, the deposition of this layer of salts upon the sheet zinc, and the constant moistness of these spots, owing to the deliquescent character of the compounds obtained, are the reasons for the destruction of the zinc. In a renewal of the covering, the use of an insulating layer of asphalt between the bricks and the zinc, or the laying of some courses of vitrified brick in the upper part of the brickwork would be recommended, in order to prevent the recurrence of the destruction of the zinc roofing.

12. Faulty Burns in the Pottery Industry

In a pottery establishment where the burning was done in a double kiln, with a compartment above the kiln space proper, and where the fire-gases were compelled to pass from the lower to the upper chamber troubles arose. These consisted principally in the fact that a portion of the tiles showed a red body, instead of the desired yellow color, while the tiles burnt in the lower compartment, which the flames reached first, were colored clear yellow, not red. At a lower temperature, obtained by wood fire instead of coal fire, a red coloration of the ware was also produced. In the upper compartment there were found much crazed ware, and also glazed tiles which were covered with little grains of salt which flowed at the highest temperatures and left behind, in part, a reddish depression.

The kiln was fired in such a manner that about 3 cubic meters of pine wood were used in the first ten or twelve hours, with gradual increase; then 40 to 50 cwt. of Bohemian lignite coal were burned in thirty to thirty-six hours, followed by 1 to 1.5 cubic meters of pine charged in two to three hours as the finishing fire.

The investigation has shown that to remove the trouble the following must happen: The red color of the ware is occasioned by the sulphurous acid coming from the coal, and contained in the fire-gases, which combines with oxygen and forms sulphuric acid, and this is taken into combination on the surface of the ware by the lime contained in the body. The lime, therefore, cannot combine with a weaker acid (the silica), since it finds a more powerful one. In consequence, the silica only combines with the alumina and the iron oxide, whose compounds are red. If these combinations still take up lime, they become yellow. In the stove-tile industry, this generally takes place, except in oxidizing burns, and when the temperature is too low to give rise to this silica-alumina-iron-lime compound. In this case, the ware is pale red, while as a rule the absorption of sulphuric acid by lime brings out a dark red color. In the neighborhood of the fire, the red coloration is always less developed than in more distant points, since the fire-gases in proximity to the fire may retain the reducing properties of the fuels themselves, while the flames at a distance become oxidizing. Air is always drawn in through the kiln walls, and is mixed with the fire-gases; again, streams of air enter through the fireplaces at the ends of the grates, which are not robbed of their oxygen by combustion because they are not thoroughly mixed with the fire-gases. They gradually mix with the residual gases. On this account, their oxidizing action first occurs at some distance and occasions there a red coloration of the ware in its path. The operation of the smoke, and the production of the yellow color of the ware by reduction, can be restrained somewhat by placing the objects in saggars if the smoke does not continue too long.

The separation of grains of salt is in the greatest part occasioned by the occurrence of potash and soda in the form of sulphates or glass-gall, and can only be traced back to a smaller extent to common salt used in the glaze preparation.

The examination of the salt crystals separated out from the glaze, which were scratched off and taken up in hydrochloric acid, gave the following composition:

	Per cent.
Residue insoluble in hydrochloric acid,	3.30
Lead oxide,	2.92
Alumina,	0.74
Calcium oxide,	5.53
Magnesia,	trace
Soda (and potash reckoned as soda),	33.83
Chlorine,	0.87
Sulphuric acid,	52.92
Total,	100.10

It is seen from the small quantity of the insoluble residue and the lead oxide, which were probably mechanically broken away with the salts, and partly taken into solution by hydrochloric acid, that the principal part of the material remains as sulphate of the alkalies and sulphate of lime, which have fused on the glaze, and which have been incorporated into the same in drop-like forms. Sulphate salts act very disturbingly on glazes; if they are present in small quantities, they rob the glaze of its luster by a thin layer of glass-gall. Here they occur in such large quantities that, collected together, they separate out as drops.

For the betterment of these conditions, the use of a reducing flame is absolutely essential; with smokeless combustion, a faultless success of the glaze burn, even with the use of wood as fuel, is scarcely possible, for even this substance always contains in its ashes some sulphate salts, which may give rise to some, if only a trifling, dimming of the glaze. This occurs the more readily from the use of bituminous coal, lignite, or peat, which always hold sulphur compounds. The sulphuric acid arising from these in burning is only rendered harmless by the use of reducing gases, that is, by causing smoke to arise by which it is converted into volatile sulphurous acid. The production of smoke is therefore desirable from beginning to end, for when once deposits and salts are locked in by the fusion of the glaze, they are protected from destruction, and it is difficult to again remove them. Only when the glaze is coming into fusion must we not smoke it too hard, because soot and metallic lead may be enclosed in the glaze.

It would be most suitable to generate heavy smoke for at least five minutes in intervals of one-fourth to one-half hour by charging the fuel plentifully. The draft must not be in the least checked, since otherwise the fire in the back part of the kiln could not make suitable progress.

Examination of Materials of the Fire-Brick and Stoneware Industries

(Prepared from the records of the Royal Porcelain Manufactory)

PROFESSOR EDWARD ORTON, JR., TRANSLATOR

I.—ANALYSES OF FIRE-BRICK, GLASS POT AND STONEWARE CLAYS

Composition according to the rational analysis.	Klingenberg clay. Per cent.	Vallendar clay. Per cent.	Clays from Seyda. I. Per cent.	Clays from Seyda. II. Per cent.	Muldenstein clay. Per cent.
Clay substance, -	84.62	93.41	79.32	83.38	61.99
Quartz, - -	8.89	5.84	18.90	13.16	35.74
Feldspar, - -	6.49	0.75	1.78	3.46	2.27
Refractoriness measured in cones, - -	——	32–33	30	30	——

Composition according to rational analysis.	Clays from Passau.					
	G. A. Per cent.	G. N. Per cent.	M. B. Per cent.	M. W. Per cent.	P. B. Per cent.	P. L. Per cent.
Clay substance, - -	93.54	93.13	87.30	94.28	94.33	90.00
Quartz, - -	5.63	4.91	6.98	3.45	2.01	7.17
Feldspar, - -	0.83	0.96	5.72	2.27	3.66	2.83
Refractoriness measured in cones, - -	——	——	——	——	——	——

The Klingenberg clay is exceptionally valuable as a glass-pot clay for the manufacture of Plumbago crucibles, and as a bond-clay for refractory material, because of its great bonding power and its ability to become dense and to vitrify at relatively low temperatures while retaining its ultimate refractoriness.

The Vallendar clay possesses likewise a high bonding power and burns, in spite of its notable refractoriness, to a thoroughly dense body at low temperatures (about cone 3).

The clays from Seyda are very fat and are suited for making gray stoneware, and to act as bond-clay for fire-brick.

The Muldenstein clay finds use in the manufacture of tiles of the Mettlach variety.

The Passau clays are used for the well-known Passau crucibles (compare the table on the following page). The refractoriness of the Rakonitz shale clay was found to be between cones 35 and 36.

The Grunau clay is only moderately plastic, contains much fine sand, and is suited for the manufacture of stoneware and of a few varieties of fire-brick. Its refactoriness corresponds to cone No. 27.

The clay from the neighborhood of Muskau burns at cone No. 05 to a pale yellow color, and at higher temperatures it becomes gray and of stoneware-like density. It is well suited for the manufacture of stoneware.

The refractoriness of a clay from Milkel, showing a considerable iron content, corresponds to cone No. 33.

Composition.	Neurode shale-clay (burnt). Per cent.	Bohemian shale-clay (burnt). Per cent.	Rakonitz shale-clay; poor quality (raw). Per cent.	Grunau clay (washed). Per cent.	Clay from the vicinity of Muskau. Per cent.	Clay from Milkel. Per cent.	Clay from Naundorf, near Rosswein. Per cent.	Clay from Naundorf, near Rosswein. Per cent.
SiO_2, - -	52.59	51.87	46.54	71.44	61.34	46.61	71.73	68.27
Al_2O_3, - -	45.30	45.99	39.15	18.83	26.17	36.47	18.64	20.63
Fe_2O_3, - -	0.74	0.52	0.85	1.22	1.77	2.81	0.74	1.45
CaO, - -	trace	trace	0.15	—	—	0.14	0.70	0.78
MgO, - -	0.40	0.45	—	0.43	1.08	—	0.41	0.50
K_2O, - -	0.68	0.72	1.11	2.67	2.48	1.44	2.49	1.71
H_2O, - -	—	—	12.86	5.79	8.07	12.80	5.25	6.66
Total, -	99.71	99.55	100.66	100.38	99.91		100.00	100.00
Clay substance, -	Both shale-clays are of exceptional refractoriness.		98.30	37.03	69.96	96.08	The refractoriness of these two clays lies between cones 32 and 33.	
Quartz, - -			1.18	54.85	29.27	1.93		
Feldspar, - -			0.52	8.12	0.77	1.99		

The clays from Naundorf possess medium plasticity and are suitable for the manufacture of stoneware. From the first Naundorf clay a sieve (71 mesh per inch) removed 25.55 per cent sand. The washed product contained 80.62 per cent clay substance, 10.73 per cent quartz, and 8.65 per cent feldspar.

2. ANALYSIS OF FIRE-BRICK, ETC.

Chemical components.	Dinas rocks, Gräfl. Sauermasche of Ruppersdorf.		Fire-bricks from Langebrieg.		Fire-bricks from Grossalmerode.			Dinas bricks from Bendorf.					Refractory bricks from Borsdorf.	Refractory cement from Gerresheim, so-called Vulcan cement.
	White. Per cent.	Yellow. Per cent.	1. Per cent.	2. Per cent.	1. Per cent.	2. Per cent.	3. Per cent.	1. Per cent.	2. Per cent.	3. Per cent.	4. Per cent.	5. Per cent.	Per cent.	Per cent.
SiO_2, - -	92.83	92.16	57.82	55.21	55.44	72.38	83.78	94.23	91.76	96.20	93.66	95.18	79.59	87.90
Al_2O_3, -	4.72	5.45	40.02	42.27	42.26	24.44	14.03	5.05	6.77	3.05	5.21	4.13	18.59	8.08
Fe_2O_3, -	0.32	0.63	1.55	1.57	1.25	1.80	1.27	—		0.50	0.72	0.49	0.85	0.58
CaO, -	1.47	1.19	0.36	0.15	—	trace	0.24	—	1.12	0.26	0.44	trace	trace	trace
MgO, - -	0.36	0.52	—	—	0.38	0.69	0.40	—	—	—	—	—	0.35	0.27
K_2O, -	0.02	0.01	—	—	0.79	1.22	0.87	—	—	—	—	—	0.85	0.64
H_2O, - -	—	—	—	—	—	—	—	—	—	—	—	—	—	2.61
Total, -	99.72	99.96	99.75	99.20	100.12	100.53	100.59	99.28	99.65	100.01	100.03	99.80	100.23	100.08

The Ruppersberg Dinas bricks show a refractoriness of approximately cone No. 36.

The rocks from Lange-Brieg are of equal refractoriness.

The Dinas bricks, 1 and 2, from Bendorf lose their shape at cone No. 30, and at cone No. 33 are melted down to shapeless masses. Cones Nos. 3 and 5 stand between Nos. 33 and 34, while No. 4 corresponds to cone No. 32.

The Borsdorf bricks have a refractoriness lying between cones Nos. 30 and 31. The Vulcan cement can be made up with water to a plastic paste, and shows, on drying from the wet-molded condition, a shrinkage amounting to 3 per cent, while on the contrary, in burning to cone No. 10, it shows a slight expansion, amounting to 0.5 per cent. Burnt at cone No. 20, it had a total linear shrinkage of 4.8 per cent. Its melting-point lies near cone No. 30.

3. EXAMINATION OF THE CLAYS FROM GROSSALMERODE

The clays of Grossalmerode are well known as refractory clays, and enjoy a good reputation in this capacity. They are especially used in the glass industry for the manufacture of glass pots, but are also used for Hessian crucibles, and for the manufacture of all sorts of refractory products.

In the manufacture of refractory claywares, they are mixed with grog, or ground hard-burnt clay, for the reduction of the shrinkage in drying and burning, and in the manufacture of Hessian crucibles they are mixed with coarse, quartz sand. The quantity and size of grain of this non-plastic material is dependent first on the fatness of the clay and next on the purpose which the wares are intended to serve.

The most highly prized clays are those which are the fattest; first, because as a rule they are more refractory than the sandy ones found in the same locations, and next, because they will carry a large addition of grog or sand without detriment to their molding qualities, and can therefore be most reduced in their shrinkage. A washing process by which the sand is gotten rid of, and by which the plasticity of the clay is improved, is not suitable for the clays of Grossalmerode. The admixed sand is, in these clays, always present in so fine a grain that it passes out with the clay and remains with it. The clays when soaked can be beaten through a sieve of 900 meshes per square centimeter without leaving any perceptible residue behind, even in the case of the impure clay which is used in the manufacture of red pottery products, and is not suited for refractory materials on account of its high content of iron oxide. A washing process would be highly necessary for the manufacture of fine whiteware, in order to remove the small quantity of vegetable fibers, rootlets, etc.

The finest ground quartz sand contained in clay reduces its refractoriness; on the one hand, it makes the clay short, and therefore hinders the possibility of adding much non-plastic material, grog or coarse, quartz sand, and on the other hand, this fine sand goes into combination with the real clay easier than that of coarser grain, and therefore expedites the fluxing. The clays containing much fine, sandy material are especially suitable for the manufacture of stoneware, because they vitrify easily and become dense at a relatively low temperature. The content of fine, quartz sand may reach 70 per cent in clays used for this purpose. The refractoriness is therefore only low.

Of the Grossalmerode clays tested, there were two from Gundlach Bros., four from H. Göbel & Sons, as well as the clay used for red pottery, which is provided with a lead glaze.

The clays carried:

(1) Fat clay from Gundlach Brothers:

	Per cent.
Clay substance (Al_2O_3, $2SiO_2$, $2H_2O$) -	89.06
Fine quartz sand, - - - -	8.79
Unweathered feldspar, - - -	2.15
Total, - - - - -	100.00

The clay substance contains 2.32 per cent of iron oxide, replacing alumina.

(2) Lean clay from Gundlach Brothers:

	Per cent.
Clay substance (Al_2O_3, $2SiO_2$ $2H_2O$), - -	46.57
Fine quartz sand, - - - -	50.90
Undecomposed feldspathic matter, - -	2.53
Total, - - - - -	100.00

The clay substance contains 1.58 per cent of iron oxide, replacing alumina.

A second shipment of these clays contained:

(1*a*) Fat clay:

	Per cent.
Clay substance, - - - - -	90.85
Fine quartz sand and feldspathic débris,	9.15
Total, - - - - - -	100.00

(2*a*) Lean clay:

	Per cent.
Clay substance, - - - -	48.51
Fine quartz sand and feldspathic débris, -	51.49
Total, - - - - -	100.00

(3) Lean clay from H. Göbel & Sons:

	Per cent.
Clay substance ($Al_2O_32SiO_2$, $2H_2O$), - -	56.66
Fine quartz sand, - - - -	43.22
Feldspathic detritus, - - - -	1.12
Total, - - - - -	100.00

The clay substance contains 1.10 per cent ferric oxide, replacing alumina.

(4) Fat clay from H. Göbel & Sons:

	Per cent.
Clay substance (Al_2O_3, $2SiO_2$, $2H_2O$), -	74.09
Fine quartz sand, - - - -	24.84
Feldspathic débris, - - - -	1.07
Total, - - - - -	100.00

The clay substance contains 2.08 per cent of ferric oxide, replacing alumina.

(5) Fat clay from H. Göbel & Sons:

	Per cent.
Clay substance (Al_2O_3, $2SiO_2$, $2H_2O$), -	71.91
Fine quartz sand, - - - -	26.29
Feldspathic debris, - - - -	1.80
Total, - - - -	100.00

The clay substance contains 2.07 per cent of ferric oxide, replacing alumina.

(6) Clay from H. Göbel & Sons, from the former fiscal clay mine:

	Per cent.
Clay substance (Al_2O_3, $2SiO_2$, $2H_2O$), -	45.64
Fine quartz sand, - - - -	53.44
Feldspathic débris, - - - -	0.92
Total, - - - - -	100.00

The clay contains 1.41 per cent of iron oxide, replacing alumina.

(7) Pottery clay from Grossalmerode:

	Per cent.
Clay substance, - - - -	62.11
Quartz sand and feldspathic débris, -	37.89
Total, - - - - -	100.00

The admixed sand was for the most part coarse-grained; the content of ferric oxide was considerable, 5.64 per cent.

For the manufacture of refractory ware, the fattest clays (1, 1*a*, 4 and 5) are best suited, because they carry the greatest amount of reducing material, grog burnt from the same clay, or coarse, quartz sand, while the less fat clays find use in the stoneware industry there carried on, using salt as the glazing material (salve-jars, pots, vessels for apothecaries, etc.).

The coarse, quartz sand which is added to the clays for the manufacture of the Hessian crucibles, which are made in a large number of small potteries, is a strongly ferruginous material. It would be possible by washing the clay to free it from a great part of the iron oxide, and the crucibles would therefore gain in refractoriness.

These clays generally assume a yellowish white color on burning up to the temperature of their vitrification, on account of their content of ferric oxide; owing to this fact they are not suitable for the manufacture of fine, white clayware (white granite and porcelain). They are exceptionally suited to the manufacture of a faint yellow-tinted C. C. ware. They were subjected to some tests in this respect, which showed the best results. Whiteware bodies were made of the following composition:

	Per cent.
Clay substance,	35
Powdered quartz,	60
Feldspar,	5
Total,	100

The quartz content of the clay was taken into consideration while the feldspar was neglected as being too unimportant.

In order to bleach the color, part of the clay substance (15 per cent) was introduced as Sennewitz kaolin (65 per cent clay substance, 35 per cent quartz).

Accordingly there were mixed:

		Parts.
(1)	Washed Sennewitz kaolin,	21
	Fat clay from Gundlach,	23
	Ground quartz,	51
	Ground feldspar,	5
(2)	Washed Sennewitz kaolin,	21
	Lean clay from Gundlach,	48
	Ground quartz,	26
	Ground feldspar,	5

These bodies behaved alike, and gave an approximately whiteware; an intense yellow was obtained from:

	Parts.
Lean clay from Gundlach,	62.5
Glazing sand from Steinberg,	37.5

The Steinberg glazing sand, which occurs in the neighborhood of Grossalmerode, at Münden, has the following composition:

	Per cent.
Silica,	85.30
Alumina, Ferric oxide,	9.79
Lime,	—
Potash,	1.92
Water and organic substance,	2.12
Total,	99.20

It consists of :

	Parts.
Powdered quartz,	65.87
Clay substance,	20.03
Feldspathic matter,	14.10
Total,	100.00

These mixtures, which are frequently used in the chemical-technical testing laboratory for nearly white and yellowish C. C. ware (the second is still being used), carry without crazing a glaze of the formula

$$\left.\begin{matrix} 0.5\ Na_2O \\ 0.5\ BaO \end{matrix}\right\} 0.1\ Al_2O_3 \left\{\begin{matrix} 2.8\ SiO_2 \\ 0.5\ B_2O_3 \end{matrix}\right.$$

which is made as follows :

(1) By fusing a frit from :

	Parts.
Heavy spar[1],	125.0
Calcined soda,	26.5
Crystallized borax,	95.5
Sand,	143.0
Charcoal,	15.0

(2) By mixing 88 parts of this pulverized glass flux with 12 parts of Sennewitz kaolin :

4. Opinions on the Raw Materials Suitable for the Manufacture of Plumbago Crucibles

As concerns the raw materials used in the manufacture of plumbago crucibles, the principal weight must be laid on the clay as the binding agent. This must be as fat as possible, in order to give the necessary cohesion to the graphite and the sand. I do not hold, therefore, that this clay must be a refractory material of the first grade ; its density will be an essential requirement. The Klingenberg clay, which certainly enjoys a good reputation for the manufacture of crucibles, is very plastic, but it does not stand, by any means, at the top in regard to its refractoriness. A sample of this clay tested by me contained :

	Per cent.
Clay substance,	84.62
Quartz,	8.89
Feldspar,	6.49

---

[1] More recently, this glaze is always made with barium carbonate (witherite) in place of the barite, in which it is necessary to replace 125 parts of barite with 98.5 parts of witherite.—THE EDITORS (German).

The refractoriness of the clay is depressed by the generally high content of ash of the graphite; indeed, I question whether the clays used for plumbago crucibles should be, as a whole, exceptionally refractory. When the crucible is ignited, the graphite burns out of the surface, and in order to guard against the complete burning out of the same, it is necessary that the crucible shall be covered with a protecting glaze film, since the crucible will become useless by the complete burning out of the graphite. This glaze forms by the penetration of the ash of the fuel, and will be taken up more readily by a not too refractory, than by an exceedingly refractory, clay. Also, it is desirable that the formation of the glaze on the surface of the crucible take place as quickly as possible, which one can perhaps favor by increasing its vitrification by addition of from 3 to 5 per cent of feldspar to the crucible body, or by dipping the outside of the burnt crucible in a soda solution. In any case, it is desirable to be able to produce a glaze film quickly when using the crucible.

The resistance of the crucible to changes of temperature will be assisted in the first case by the graphite content, and also, the feldspathic bodies always prove less sensitive to temperature changes than those free from feldspar.

The Klingenberg clay contains notable quantities of feldspar, and this may have contributed to its reputation as a crucible material.

Examination of Materials for the Whiteware and Porcelain Industries

(Prepared from the records of the Royal Porcelain Factory)

PROF. EDWARD ORTON, JR., TRANSLATOR

1. ANALYSES OF THE WHITEWARE CLAYS OF LOTHAIN

The results of the investigation of the whiteware clays of the Messrs. Rühle have been for the most part published already in the *Thonindustrie Zeitung*, for the year 1882.

Ingredients.	Whiteware clays.		Lothain Rittergut glasspot clay from the Gertrude shaft. (1886)	Average of ten white-burning samples from Römer shaft. (1887)	Clay from the Erich and Gertrude shafts. (1888)	Clay from the Römer shaft. (1891)
Per cent.	I-1882. Per cent.	II-1886. Per cent.	III. Per cent.	IV. Per cent.	V. Per cent.	VI. Per cent.
SiO_2 -	54.51	56.09	59.58	66.05	58.40	79.58
				($0.39\ TiO_2$)	28.88	
Al_2O_3 -	31.41	30.10	28.68	23.98		13.51
Fe_2O_3 - -	0.68	0.76	1.16	0.61	1.09	0.56
CaO - -	0.04	0.38	0.07	0.38	0.36	trace
MgO -	0.43	trace	trace	trace	trace	0.32
K_2O - -	0.55	0.69	0.54	0.14	0.31	0.43
H_2O -	12.37	12.20	9.87	8.61	10.98	5.40
Total - -	99.96	100.24	99.90	100.16	100.02	99.80

RATIONAL ANALYSES

Clay substance,	83.04	80.15	74.28	61.03	76.25	35.40
Quartz, -	16.28	19.20	25.72	37.79	23.12	62.84
Feldspar,	0.68	0.65	trace	1.18	0.63	1.74
Total,	100.00	100.00	100.00	100.00	100.00	100.00

COMPOSITION OF THE CLAY SUBSTANCE CALCULATED FROM THE FOREGOING

SiO_2	45.53	45.30	45.66	44.78	45.73	....
				($0.65\ TiO_2$)		
Al_2O_3,	37.68	37.25	38.62	38.91	37.12	....
Fe_3O,	0.82	0.94	1.57	1.00	1.42	....
CaO,	0.05	0.47	0.09	0.62	0.47	....
MgO,	0.51	trace	trace	trace	trace	....
K_2O,	0.52	0.86	0.72	0.26	0.26	....
H_2O,	14.88	15.18	12.29	14.11	14.40	....

Theory requires for clay substance, Al_2O_3, $2SiO_2$, $2H_2O$:

	Per cent.
Silica,	46.33
Alumina,	39.77
Water,	13.90

With the exception of the clay tested in the year 1891, whose plasticity is not excessive but is sufficient for the whiteware industry, all these clays are of exceeding plasticity. They burn white, without exception, at low temperatures up to a temperature corresponding to the fusion of the feldspar (about cone No. 10), which is only attained in the biscuit burn of the non-calcareous feldspathic whiteware. In the finishing fire of hard porcelain, which attains cone No. 18, clays I, II and IV, take on a feeble yellow color, while clays III and V burn at this temperature with more or less marked increase in density, becoming gray on the fracture and brown on the surface, in consequence of oxidation setting in on cooling.

From the above, we see that clays I, II and IV are especially noteworthy in the manufacture of porcelain and whiteware products for increasing the plasticity of the bodies. Seger used Lothain clay exclusively as the plastic ingredient in the production of the well-known soft porcelain named "Seger-porcelain" in his honor.

Clay VI is to be regarded as a whiteware material, while clays III and V are preeminently suited for refractory materials.

The refractoriness of clays I to IV approximates that of the Zettlitz kaolin, while V melts between cones Nos. 31 and 32 and clay VI fuses simultaneously with cone No. 27.

2. TESTS OF KAOLINS

Earths from the vicinity of Halle:

Raw kaolin (A) from Lettin, burnt to a pure white in the porcelain fire:

	Per cent.
Sand removable by washing, over 0.2 mm. diameter of grain,	19.67
Fine sand, not separable,	16.81
Feldspathic residue,	3.01
Clay substance,	60.51

Raw kaolin (B) from Lettin, burns pure white in the porcelain kiln without sticking together:

	Per cent.
Coarse sand above 0.2 mm. diameter,	16.70
Fine sand, 0.2 to 0.05 mm. diameter,	6.20
Silt, 0.05 to 0.01 mm. diameter,	9.80
Clay substance, under 0.01 mm. diameter,	67.30

The clay substance contains:

	Per cent.
SiO_2,	49.80
Al_2O_3,	33.70
Fe_2O_3,	1.00
CaO,	0.94
MgO,	trace
K_2O,	1.33
H_2O,	13.15
Total,	99.92

Rational analysis:

	Per cent.
Clay substance,	92.24
Quartz,	7.66
Feldspathic matter,	0.10

The kaolin stands near to the Zettlitz kaolin in reference to its refractoriness; a porcelain body made from

	Parts.
Washed kaolin,	100
Quartz sand from Hohenbocka,	31.8
Feldspar,	35.9

corresponding to

	Per cent.
Clay substance,	55.0
Quartz,	23.5
Feldspar,	21.5
Total,	100.0

burnt to a beautiful white, and was transparent.

Washed kaolin (C) from Lettin. This material, similar to the preceding, contains:

	Per cent.
Clay substance,	87.40
Quartz,	11.65
Feldspar,	0.95

corresponding to

	Per cent.
SiO_2,	53.29
Al_2O_3,	32.80
Fe_2O_3,	1.13
CaO,	0.31
MgO,	0.20
K_2O,	0.72
H_2O,	11.54
Total,	99.97

Accordingly the composition of the clay substance is :

	Per cent.
SiO_2,	46.94
Al_2O_3,	37.31
Fe_2O_3,	1.29
CaO,	0.35
MgO,	0.23
K_2O,	0.65
H_2O,	13.20

Kaolin (D) from Lettin. Lower portion of the bed :

	Per cent.
Clay substance,	29.97
Quartz,	35.09
Feldspar,	34.94
Total,	100.00

This perfectly white-burning slightly plastic product, which forms, at the melting-point of feldspar, an enamel-like self-glaze may be used partly as a substitute for feldspar in the manufacture of porcelain bodies. A body consisting of

	Per cent.
Kaolin (D),	71
Zettlitz kaolin,	29

corresponding to

	Per cent.
Clay substance,	50
Quartz,	25
Feldspar,	25

proved itself beautifully white-burning and translucent.

Kaolin (E) from Bitterfeld :

	Per cent.
Clay substance,	38.46
Quartz,	42.63
Feldspar,	18.91

Kaolins F and G from Dölau

	(F) Per cent.	(G) Per cent.
Clay substance,	85.67	88.00
Quartz,	11.90	8.59
Feldspar,	2.43	3.41

Both of these earths burn white, and enjoy a wide-spread fame as materials for the manufacture of porcelain and white-ware. With the second kaolin, a porcelain was made containing

	Per cent.
Clay substance,	50
Quartz,	25
Feldspar,	25

in which 56.8 parts of Dölau clay was mixed with 20.1 parts quartz sand from Hohenbocka, and 23.1 parts feldspar.

This body is not very plastic. For increasing the plasticity, additions of Lothain kaolin, whose average proportion of clay and quartz stands in the ratio of 4 : 1, were made by 5 per cent increments.

The following bodies are of sufficient plasticity, and show an approximately uniform behavior in reference to the refractoriness:

I

		Clay substance. Parts.	Quartz. Parts.	Feldspar. Parts.
Lothain clay,	5.0 parts,	= 4.0	1.0	0.0
Dölau earth,	52.5 "	= 46.0	4.7	1.8
Sand from Hohenbocka,	19.3 "	= —	19.3	—
Feldspar,	23.2 "	= —	—	23.2
		50.0	25.0	25.0

II

		Clay substance. Parts.	Quartz. Parts.	Feldspar. Parts.
Lothain clay,	10 parts,	= 8.0	2.0	—
Dölau earth,	47.7 "	= 42.0	4.1	1.6
Sand from Hohenbocka,	18.9 "	= —	18.9	—
Feldspar,	23.4 "	= —	—	23.4
		50.0	25.0	25.0

III

		Clay substance. Parts.	Quartz. Parts.	Feldspar. Parts.
Lothain clay,	15 parts,	= 12.0	3.0	—
Dölau earth,	43.2 "	= 38.0	3.7	1.5
Sand from Hohenbocka,	18.3 "	= —	18.3	—
Feldspar,	23.5 "	= —	—	23.5
		50.0	25.0	25.0

With the increasing content of Lothain clay, the bodies became more plastic and required to be handled more carefully in fettling. Especially, they must not be allowed to become too dry before fettling; the more Lothain clay they contain the denser they become on drying, and have a fire shrinkage correspondingly less.

SILESIAN CLAYS AND OTHER MATERIALS

ULTIMATE ANALYSIS

Ingredients.	Kaolins from Ruppersdorf Grafl. Sauerma Clay Pits.					Kaolin from Göppersdorf.	Product of feldspathic weathering from Birkenfeld.	Norwegian feldspar.	Fürstenwald glazing sand.
	1 Per Ct.	2 Per Ct.	3. Per Ct.	4. Per Ct.	5. Per Ct.	Per Ct.	Per. Ct.	Per Ct.	Per Ct.
SiO_2,	47.43	48.54	46.21	....	....	49.42	73.82	64.34	....
Al_2O_3,	38.86	39.12	39.34	....	....	36.69	15.92	22.52	....
Fe_2O_3,	2.09	1.73	1.14	....	....	0.73	0.52	....	....
CaO,	0.77	1.35	trace	....	....	0.09	0.21	2.92	....
MgO,	0.58	0.03	....	....	....	trace	0.92	....	....
K_2O,	0.20	trace	0.69	....	....	0.43	3.34	0.91	....
Na_2O,	....	....	....	....	....	....	1.96	9.12	....
H_2O,	10.72	9.53	12.49	....	....	12.07	2.86	0.47	....
Total,	100.65	100.30	99.87	....	....	100.06	99.59	100.28	....

RATIONAL ANALYSIS

Clay Sub'tce	94.32	98.79	99.99	87.31	72.31	89.52	40.21	....	3.16
Quartz	3.68	0.36	0.26	9.79	26.16	3.73	32.99	....	5.42
Fel'par	2.00	0.85	1.84	2.93	1.50	6.75	26.80	....	91.42

The kaolin marked 1 (washed) is, when unwashed, strongly arenaceous; it is tolerably plastic, looks greenish white in the raw condition, and burns whitish gray in the porcelain kiln. Its melting-point lies between cones Nos. 35 and 36.

The kaolin marked 2 was likewise examined in the washed condition; unwashed, it contains much quartz. Its color on burning is light gray, and its refractoriness corresponds to cone No. 35.

The kaolin marked 3 was not washed; it burns at light yellow, and melts at cone No. 35.

Those marked 4 and 5 are but little refractory.

The Goppersdorf kaolin, from the pits of the Freiherr von

Thielmann, is of medium plasticity, and burns white in the porcelain kiln. Its refractoriness corresponds to cone No. 34.

The feldspar-like material from Birkenfeld is the product of weathering of a feldspathic rock, possibly of syenite. In its constitution, it resembles Cornish stone; it burns very white, and, mixed with kaolin, may be used as a substitute for feldspar in the whiteware industry.

The feldspar coming from the vicinity of Frederiksstadt represents a white crystalline body, translucent on the corners, and shows no visible inclusions of quartz and mica. In the porcelain kiln, it melts wholly free from specks. The material, almost free from potash, is an albite, with some lime, and of great fusibility. The Fürstenwald glazing sand burns white, and is much in use in the manufacture of bodies and glazes.

Clays from the Kingdom of Saxony

MEISSEN EARTHS

The unwashed earths contain:

	Seilitz-Meissen. Per cent.	Lothain-Meissen. Per cent.	Porcelain-sand obtained by washing. Per cent.
Clay substance,	38.89	57.46	10.21
Quartz, - -	54.11	41.11	79.96
Feldspar, -	7.00	1.43	9.83

Washed clay from Seilits-Meissen.

	Per cent.
Clay substance, - - - - -	80.99
Quartz, - - - - - - -	16.66
Feldspar, - - - - - -	2.35
Total, - - - - - -	100.00

	Total. Per cent.	Of the clay substance. Per cent.
SiO_2, - - - -	56.15	46.00
Al_2O_3, - - - - -	32.00	38.82
Fe_2O_3, - - - -	0.64	0.78
CaO, - - - - -	0.33	0.40
MgO, - - - -	trace	trace
K_2O, - - - - -	0.47	0.06
H_2O, - - - -	10.81	13.30
Total, - - -	100.40	99.96

The kaolins burn pure white, and are prized for the manufacture of porcelain, especially since they possess a certain plasticity. The sand also burns pure white, and is very well suited for the making of porcelain bodies.

Clays and sands from Kemmlitz:

	1. Per cent.	2. Per cent.	3. Per cent.	4. Per cent.
Clay substance,	47.50	77.64	20.20	36.37
Quartz,	51.58	21.58	79.68	61.74
Feldspar,	0.92	0.78	0.16	1.89

1. Unwashed clay.
2. Washed earth clay.
3. Quartz sand.
4. Matter washed out.

The washed clay contained:

	Total Per cent.	Of the clay substance. Per cent.
SiO_2,	59.53	48.20
Al_2O_3,	29.71	38.07
Fe_2O_3,	0.33	0.42
CaO,	0.12	0.15
MgO,	trace	trace
K_2O,	0.61	0.61
H_2O,	10.06	12.95
Total,	100.36	100.40

All these materials burn to a spotless white in the porcelain kiln, and are suited, according to their character, for the manufacture of porcelain.

FOREIGN EARTHS

1. Kaolins from Podersam in Bohemia (washed):

	I. Per cent.	II. Per cent.
Clay substance,	88.10	92.86
Quartz,	10.95	5.92
Feldspar,	0.95	1.22

Both kaolins, in the highest heat of the hard porcelain kiln, are white-burning with a touch of yellowish, and are suited to the manufacture of porcelain, whitewares, and other fine ceramic products.

2. English Kaolins (from Dressel, in Coburg):

	A. Per cent.	D. Per cent.
SiO_2,	47.47	48.28
Al_2O_3,	38.79	37.64
Fe_2O_3,	0.44	0.46
CaO,	0.07	0.06
MgO,	trace	....
K_2O,	1.14	1.56
H_2O,	11.92	12.02
Total,	99.83	100.02

Rational analysis:

	Per cent.	Per cent.
Clay substance.	94.25	94.25
Quartz,	1.26	0.98
Feldspar,	4.49	4.77

From which the clay substance has the calculated composition:

	A. Per cent.	D. Per cent.	Theoretical. Per cent.
SiO_2,	45.93	46.89	46.33
Al_2O_3,	40.29	38.99	39.77
Fe_2O_3,	0.46	0.49	.....
CaO,	0.07	0.07	.....
K_2O,	0.39	0.89	.....
H_2O,	12.76	12.76	13.90
	99.90	100.09	100.00

These kaolins or china clays are of extraordinary purity as regards the composition of their clay substance; they burn pure white in the severest porcelain fire, and show small inclination to warp or twist. Their refractoriness corresponds to cone No. 35.

3. Kaolin from Limoges (France):

	Per cent.
Clay substance,	96.91
Quartz,	2.32
Feldspar,	0.77

This material burns excellently white, and belongs to the same class as the previously described English kaolins, in every respect.

4. Mexican Kaolins:

	A. Per cent.	B. Per cent.
Clay substance,	97.72	95.80
Quartz,	2.28	4.20
Feldspar,	....	....
Total,	100.00	100.00

The unwashed kaolins burn an excellent white, but are of such exceedingly small plasticity that a body made from 56 parts of kaolin, 21 parts of sand and 23 parts feldspar is no longer workable on the wheel.

3. CONCERNING THE CAUSE OF THE ROLLING-UP OF THE GLAZE LAYER

The rolling-up of the glaze layer on the edges and raised parts of the ware, by which the body appears free from glaze at these points, may have as its cause either too fine grinding of the glaze or an efflorescence of crystalline salts between the body and glaze-coat.

(1) The too fine grinding of the glaze generally shows at the point where the glaze layer is thickest, where it cracks open in drying. This fault can be detected after the drying of the dipped ware. It shows the glaze in the thicker-lying portions to be penetrated by little hair-cracks. The occurrence of this defect may be ameliorated by less fine grinding of the glaze, and when it cannot be helped in this way, by reduction of the plastic ingredients of the glaze, which must be replaced by substitution of an equivalent quantity of calcined ingredients.

(2) The presence of salts, generally sulphates of lime or magnesia, in considerable quantities (for instance, 0.1 to 0.2 per cent) in the body has, as a consequence, the collection of these more or less soluble salts on the aforesaid spots, the edges and raised places, during the drying of the turned ware, and the crystallization of the substances collected. Unglazed wares afflicted with this trouble show, after coming from the biscuit burn, that they are covered on these spots with a thin smooth

glaze-like skin. We can see these separations on the biscuit wares very easily with the help of a magnifying glass; if the salts are also ferruginous, they can at once be recognized by the yellow or reddish coloration, which the edges of the plates show after biscuit burning. This layer of salts lying on the body hinders the contact of the body with the glaze layer and therefore a rolling up of the edges of the latter easily takes place, as soon as the latter begins to shrink in burning. The salts which give rise to this phenomenon come either from the water used in softening the body, or in case the clay is dried on plaster plates, they are absorbed from them or out of the plaster molds (which are soluble in water in the ratio of 1 : 400), and come upon the surface of the product, or they are present in the clays; or in case the body is ground, they may come from the mills into the body, since the porcelain lining of the mills is ordinarily put together with plaster of Paris. In most cases, this trouble is best overcome by addition of chloride, of barium, or witherite ($BaCO_3$) to the body, by which the soluble salts are converted into insoluble forms.

4. CONCERNING THE ORIGIN OF YELLOW SPOTS ON BISCUIT-WARE

Yellow colorations on the surface of white or porcelain wares appear after the biscuit burn, if soluble iron salts occur in the clay. Especially in the clays of Höhr and Grenzhausen, which are generally exported as Vallendar of Dutch Ball clays, show, after long weathering on the sides exposed to the air, intensely yellow or yellowish brown colorations, while the inner portions of the lumps remain white. After burning, they retain these discolorations, which can be traced back to the fact that the iron salts contained in soluble form in the clays have been carried to the surface by the evaporating water and there deposited.

Soluble iron salts may arise by the weathering of a small quantity of iron pyrites, which is then converted into ferrous sulphate and iron oxide, or by the operation of the never-absent organic substances on iron oxide.

This efflorescence of these compounds may be hindered by converting them into insoluble double salts by addition of a little quicklime. In general, 0.1 per cent of calcium oxide is sufficient, which quantity is without ill effect on the clay.

A second cause for the occurrence of yellowish or brown colorations on the surface of biscuited wares may be the volatilization of iron compounds from the bituminous coal.

The bituminous coals are never wholly free from chloride of soda or fluorine compounds, and chloride or fluoride of iron is volatile. The chlorine compounds, especially, often give rise to this phenomenon.

5. THE INVESTIGATION AND METHOD OF PREPARATION OF A BLACK COLOR FOR MUFFLE-FIRE

The chemical analysis of the color gave the following result:

	Per cent.
SiO_2,	19.10
PbO,	57.27
CuO,	5.75
Mn_2O_3,	7.30
CoO,	6.14
CaO,	trace
MgO,	trace
Na_2O,	1.43
B_2O_3,	3.22
Total,	100.21

If we mix the metallic oxides with the required flux, as calculated from the above analysis, we always obtain only an impure, grayish black stone, shading into blue, since it is not possible to mix the oxides intimately enough with each other.

It is necessary in the preparation of a serviceable black color to dissolve the oxides in an acid, or supply them in the form of their salts soluble in water. For the production of the above color the following were used:

	Parts (by wt.)
Crystallized sulphate of copper,	18.00
" " " manganese,	20.3
Anhydrous sulphate of cobalt,	12.60

The solution was treated with sodium carbonate, until it gave only a feeble alkaline reaction, boiled a long time, and then washed with hot distilled water until barium chloride gave no more reaction for sulphuric acid. The precipitate collected on a filter, dried and ignited at muffle heat looks black, and makes a crumbly powder.

For the manufacture of the color, 20 parts of the preparation were rubbed together with 80 parts of a flux prepared at muffle heat:

	Parts (by wt.)
Powdered quartz,	20
Red lead,	60
Crystallized borax,	9.5

The coloring compound rubbed with the clear flux gives a deep black color at muffle heat.

INDEX

PAGE
Analysis of clay, chemical and rational 537
— of clay, mechanical 41
— fire-brick, glass, pot and stoneware clays . . . 1127
— fire-brick 1130
— whiteware clays of Lothain 1137
Apparatus, Orsat's 76
— Schoene's washing 44
Barium as an addition to clay in making face-brick . . 396
— glaze 606
— sulphate as a glaze material 634
Bisque body 707
— ware, cause of yellow spots in 1148
Bock, tunnel kiln 271
Bornholm, its clay industry 950
Braunite from Luthersteufe 448
Bricks, at Berlin exposition, 1879 931
— at Paris exposition, 1878 888
— at Vienna exposition, 1873 817
Brick industry of Belgium and Lower Rhine . . . 762
— of England 783
— of Northern France 883
Brick clays, from Helmstedt 1114
— incompleteness in the investigation of . . . 32
— quartz sand in 390
— from Wickendorf, near Schwerin 1113
Bricks, colors of 360
— glazed building 419
— investigation pertaining to the color of . . 347
— natural colors and discolorations of . . . 347
— note on colors of 343
— paving and clinker, clay especially suited for . . 415
Clay, burning of calcareous 971
— calcium carbonate in 336
— chemical and mechanical examination of . . 537
— Carlsburg, from 1111
— coloration of brick 106
— constitution of plastic 69
— contribution to a better knowledge of properties of . 477
— determination of refractoriness of 525
— Eifel, from 1118
— engobe 438

PAGE

Clay, examination of the Hainstedt . . . 999, 1002, 1116
— for stove tiles from Mühlenbeck 435
— Förderstedt, from 1115
— gaps in examination of 32
— Grossalmerode, from 1131
— industry of Staffordshire 769
— influence of fire-gases on 123
— influence of titanic acid on 519
— mechanical analysis of 41
— relation between plasticity and refractoriness . . 533
— stoneware of Hoehr 445
— the influence of the mineral constitution on the fusibility of . 486
— water in burning 213
— what properties must it possess for the manufacture of paving brick? 415
— whiteware from Lothain 1137
Clayware, action of water in burning 213
— coloration by iron at high temperature . . . 1027
— fine, at the Paris Exposition, 1878 . . . 902
— Indian, at the Vienna Exposition, 1873 . . . 829
— influence of sulphur in coal on burning . . 369
Color mill 667
Colored glazes, for whiteware 615
— for Seger porcelain 725
Colored porcelain 704
Colors, underglaze 651
— natural and discoloration of light-colored bricks . 347
— black, for muffle fire 1149
Composition and fusibility of some feldspars . . . 570
— and specific gravity of generator gas . . . 211
— of a bisque body 707
— of brown slip glazes 449
— of some foreign hard porcelain bodies . . . 678
— on the relation between, and the behavior in burning of the Sennewitz kaolins 669
— and fusibility of some feldspars 520
— and effect of fire-gases in ceramic kilns . . . 135
— and temperature of the fire-gases in the continuous kiln . 206
Continuous kiln, gas-fired 211
Crucibles, plumbago, opinion on raw materials suitable for . . 1136
Crystallization and its significance 8
Cuprous oxide glazes 708
Defects of glazes 557
Defence against Olschewsky 992
Discoloration of clayware 347, 381
Dryer, Bock 271
Drying in the open air and closed chambers . . . 251
Earthenware and stoneware clays 435, 445, 449

PAGE
Efflorescence on brick fronts, green and yellow . . 381
— on terra cotta 376
English pottery 769, 821, 912
— brick industry 783
— kaolins 1146
Engobe clays 438
Examination of industrial kiln gases 81
— of fine whiteware bodies 553
— of matt roofing tile glaze 421
— of two floor tiles 920
Exposition at Berlin, 1879 931
— at Paris, 1878 888
— at Vienna, 1873 817
Face-bricks, their discoloration 347
Faience, Persian 470
Fire-clays 477, 486, 525, 533
Fire-gases, analysis of 97
— composition and effect of 135
— influence of, upon clays and color phenomena . . 123
— investigation of, in continuous kiln with Orsat apparatus . 82
— temperature and composition of, in some continuous kilns 206
Floor and wall tiles 897
Fuerstenwalde glaze sand 442
Fusibility and composition of some feldspars . . . 520
Gas-firing at Greppin, failure of 316
Gas retorts, manufacture of 921
Gauge, draft and pressure 218
Glass sand, Fuerstenwalde 442
— coloration of, by iron 1038
Glazes, barium 606, 634
— calculation of 1119
— colored 615, 725
— composition of brown slip 449
— defects of 557
— copper-red 733, 1042
— dull roofing tile 421
— free from lead 453, 593
— porcelain 695, 708
— rolling-up, cause of 1147
— sand, for 442
— tin, for stove tile 1119
— for velten clay, ... 1121
— whiteware 593, 634
Hard porcelain bodies 678
— glazes 695, 708
Heavy spar, in glazes 593
Hoehr stoneware clay 445

PAGE

Indian claywares 829
Iron, its coloring effect 1027, 1038
Italian pottery 866
Kaolin, English 1146
— contribution to the better knowledge of 62
— from Limoges 1141
— Mexican 1147
— Podersam (Bohemia) 1145
— relation between composition of, and behavior in burning 669
— test of 1139
Kiln, continuous, fired with gas for burning claywares 316
— continuous lime, investigation of gases in 82
— continuous, notes on the theory of firing 333
— continuous, water-smoking process in 276
— trial for ceramic purposes 222
Lead glazes 426
Lead free glazes 453, 593
Manufacture of dust-pressed bricks 801
— of gas retorts 921
— of sewer pipe 843
Majolica 866, 897, 940
Melting-point determinations 1005, 1008
Mills for grinding colors 667
Mortar, weathering of 432
Mosaics, clay 474
Orsat apparatus 76
Paving brick and clinkers, Oldenburg 759
Persian faience 470
Plasticity and refractoriness 424
Plastic clays, constitution of 69
Plumbago crucibles, opinion on raw materials suitable for 1136
Podersam (Bohemia) kaolin from 1145
Porcelain, coloration of, by iron 1041
— colored 704
— composition of some foreign bodies 678
— glazes 708
— hard-fire 678
— Japanese 708
— Seger 708
— Wegeli 700
Pottery, French 830, 902, 959
— English 769, 821, 912
— German 877, 931
— Italian 866
— Staffordshire 769
Pyrometers and measurement of high temperatures 224
Pyrometric cones for determination 224

PAGE
Pyrometic cones at high temperatures 1017, 1022
— cones, controversy vs. Bischof 1005, 1008, 1013, 1020
— tests by Dr. Jochum 1024
Quartz sand in brick clay, and one of its peculiar effects 390
Refractoriness and plasticity of clays, relation between 533
— of clays, determination of 525
Rolling-up of glazes, cause of 1147
Sand, Fuerstenwalde, glaze 442
— volcanic, from the Eifel mountains 447
Schoene's washing apparatus 44
Seger porcelain 708
Sewer pipe, manufacture of 843
Smalt, examination and preparation 1121
Staffordshire potteries 769
Standard cones. See pyrometric cones.
Stoneware clays 435, 445
— industry in Nassau district 809
Stove industry 869, 935
Sulphur in coal, influence upon clayware 369
Sulphuric acid in glazes and bodies 645
Traveling reports 759–959
Terra cotta, discolorations of 376
Tile clay from Muehlenbeck 435
Tin glaze for stove tile, investigation of 1119
Titanic acid, effect of, on fusibility of clays 519
Union centrale, exhibition of 959
Underglaze colors 651
Vanadium compounds in lignite clay and discolorations caused by them 385
Volcanic sand from the Eifel mountains 447
Wall and floor tiles 897
Washing apparatus, Schoene's 44
Water in burning of clayware, action of 213
Weathering of crystalline rocks and its influence on the structure of clay bodies 1
Weather-resisting power of old Roman bricks and mortar 432
Wegeli porcelain 700
Whiteware bodies 553
— colors 615
— decoration 622
— glazes 593–634
Zinc trimmings, cause of destruction 1121

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